Members are asked to contribute discussions of papers in this issue of the Journal for publication in the next issue.

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1925—1926.

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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

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This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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New England Water Works Association

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

FINANCING MAIN PIPE EXTENSIONS BY THE ASSESSMENT METHOD.

BY CALEB MILLS SAVILLE.*

[*Read September 10, 1925.*]

At the outset it should be stated that the object of this paper is to set forth some of the incidents that have occurred in connection with the use of the Assessment Method of Financing Main Water Pipe Extensions in Hartford, Conn.

A special assessment "is a local assessment imposed occasionally, as required, upon a limited class of persons interested in a local improvement, who are assumed to be benefited, and it is imposed and collected as an equivalent for that benefit and to pay for the improvement." (*City of Bridgeport* (Conn.) vs. *N. Y., N. H. & H. R. R.*, 36 Conn. 225, 262, 263; Am. Rep. 63.) "The foundation of special benefits for public improvements is the special benefit derived by owners of property over and above the rest of the community." (*Newell* vs. *City of Cincinnati*, 450 s. 407, 424; 15 N. E. 196 (1887.)

No one can reasonably deny that the extension of the public water supply into new territory is of special benefit to that locality. How this extension shall be paid for is a problem that has vexed most water-supply officials, and it is one which will not down but is continually in evidence. There are two distinct phases of this question — viz.: whether it is approached from the viewpoint of the privately owned water company or whether it is seen from the angle of the municipally owned and operated system.

In the first case the method is simple, even if the means are not always at hand. The extension is a capital expense and should be met from income preferably, of course, from surplus. Sound bookkeeping allows the use of the depreciation fund for this purpose, provided the money is borrowed from that fund as from any source, and interest paid for the use thereof. This source of funds is available both to privately and municipally operated plants.

In the second case, that of municipally operated plants, theoretically, at least, and usually practically, as well, there is no surplus, for the works

* Manager and Chief Engineer, Board of Water Commissioners, Hartford, Conn.

are run at cost. The stockholders, who are the water-users, take their dividends as long and as often as possible in low rates from the service. As human nature is prone not to tax itself to a greater degree than possible the continually starved condition of such works is easily understood.

Several methods are available to municipally operated works, all of which are probably open to more or less objection.

If all water income is turned into the muncipal treasury, the usual way to meet the cost of capital expense is by direct appropriation from the tax levy, or from bond issue for the specific work.

If the water department handles its own funds, there are two methods in ordinary use at the present time: The guarantee method, by means of which the developers of property promise a certain return to the department in water rents, or otherwise, if the pipe is laid. There are many pitfalls along this path. The guarantee is usually personal and the guarantor may move away. All of the property-owners on the street may not be willing to sign, but as it is a public pipe they have certain rights that cannot be denied even if they are not holden for the initial expense of the installation. At any rate, whether they connect or not, their property has been greatly benefited by the installation, at no cost to them. To avoid this inequality and, as nearly as possible, collect from the beneficiary for value received, the method of assessment for main-pipe extensions seems to be the more equitable one for all concerned.

After long and somewhat trying experience with the so-called guarantee system of financing main-pipe extensions, under authority of a legislative act the Board of Aldermen of the City of Hartford approved an ordinance which provided for the assessment of benefits from main-pipe extensions. The text of the ordinance under which the Hartford Water Board now operates will be found as an appendix to this paper. This method of financing main water-pipe extensions has worked out very satisfactorily in Hartford, and there are few persons who would be satisfied to return to the former method.

Many difficulties have been encountered in working by this method, and it is the purpose of this paper to mention some of them as a help to other water department management.

The initial step toward installing a main water pipe in a new location is for the proponent to present a petition to the Board of Water Commissioners. At a stated time, which is now the first Monday of each month, the board meets to consider main-pipe extension arguments for and against the proposition. The board then takes the matter under advisement and determines if public necessity and convenience require the extension. An accompaniment of this method is its relationship to convenience and necessity rather than the cost of the work or even the means available for doing it.

After a petition is received the records regarding the property are examined and a plan prepared showing all lot-owners affected on each

side of the street. All owners are notified of the proposed hearing, which is also advertised in the newspapers. As it would be manifestly unfair to assess both frontages on a corner lot for the full amount of the assessment, by vote of the board an exemption of 75 ft. is made when a pipe is laid on the second side of the property. Even this exemption is the subject of considerable controversy, and at times seems to bear heavily upon the owner of the property. For example, there are sometimes corner lots that result in a very acute angle; the lot may have considerable frontage on both streets, but most of the area may be too narrow in residential districts to permit of a suitable building. Here the owner protests that he has water from one street, needs none from another side, and at any rate the lot is too small for further development. Again, the lot may be of such a depth from one side that, with the house set back of an established building line, there is no room for another dwelling on the side street, and the owner is amply served from a pipe laid previously.

It is hard to convince these owners of the justice of the assessment, but in the end it is surprising how few real protests are allowed to continue after the matter is thoroughly explained and the good to the greatest number stressed. Of course there are some protesters whose whole argument rests on the fact that they now have water either by fronting on another street, or through a supply by a private pipe, and they allege there is no reason for assessing them for the benefit of others. They, too, are few, and their protests are not heeded if there seems reasonable evidence that the district should be served.

This method of financing main-pipe installations is generally conceded to have been a boon to real-estate development, as it places the cost of the improvement equally on all property along the street and, being added by the developer to the price of the land, results in little or no hardship on the purchaser. At present the maximum rate of assessment is $1.75 per front ft. With a 50-ft. lot $87.50, added to the price of the lot, is negligible in comparison with the advantages of having city water in the street. Under the former guarantee method of 10 per cent. of the cost in water rents or otherwise, oftentimes the guarantor would for years have a payment to make, and in some cases even after a street was fully developed the income would not amount to 10 per cent., and the guarantor was theoretically held forever.

As an aid in deciding whether or not public convenience or necessity requires the installation at the time requested, it is the usual custom for the board to assure itself that the resulting income will return a proper return on the portion of the investment made by the board which cannot be assessed against abutting property. This, however, is only incidental and cannot be used as a main argument.

It has been found that generally the average water rental under Hartford rates is from $8 to $10 per year. Bungalow-type houses will return from $6 to $7. Two and three-family apartment houses, respectively,

from $12 to $18 or $20 per year, and, of course, full-plumbed single houses of the first class will return considerably more, averaging usually from $15 to $18 per year. If the return in water rates will average 6 per cent. or 7 per cent. on the portion of the investment borne by the water department, a strong factor is at hand for favorable consideration at the request for extension.

In the ordinance under which the work is done, the cost of laying a 6-in. pipe in the given street is used as a basis for assessment, on the theory that this size pipe is reasonably demanded for local fire protection. This size pipe, however, is seldom laid, its only use being in short streets fed at both ends, or as a variant in longer streets with no side branches. Up to 600 ft. of 6-in. pipe is often laid in the middle and fed at both ends by an 8-in. pipe. This method somewhat reduces cost to the department and results in no detriment to the service, as only one hydrant is ever taken from this section. The maximum length to the hydrant is not allowed to exceed 300 ft., and the hydrant is then supplied from each side.

The ordinary size, therefore, for residential streets is 8-in. diameter, and this size is, of course, increased wherever required for development or otherwise. The difference in cost of installation between the 6-in. and 8-in. pipe is, of course, an excess charge to be borne by the department. Besides this, the cost of connections and exemptions on corner lots has to be absorbed in some way.

During the first three years, 1920, 1921, and 1922, the cost of laying 6-in. pipe for the previous year was used as the criterion. In 1922, however, due to several very long lines of 6-in. pipe laid by machine in dirt roads, the cost was extremely low. The next year, in making up the estimates it was seen that the result of using this price under ordinary conditions would be to place a very heavy burden on the department. Due to this condition the ordinance was changed, and the base price determined from the average cost of the 6-in. pipe work for the preceding five years. (See Table 1.)

To the average cost thus determined is added a percentage for overhead, which in the aggregate amounts to about 23½ per cent.

This figure is arrived at by addition to the base cost: first 15 per cent. on labor cost, which includes general supervision and use of tools, clerical work, etc.; second, 10 per cent. on material cost which includes handling, inspection, clerical work, etc.; third, 10 per cent. to the sum of the labor and material costs included as above for general office work, vacations, sick leave, pensions, engineering, etc. In other words, it is the intention to pass on to the abutting owner the proportional cost of all expenses that may legitimately be considered a part of the work from the time it is initiated until its end.

At first the average cost of the work for assessment and comparison with the base cost was obtained by dividing the total cost of the work by the total length laid, and this price per foot applied to the assessable frontage, the board absorbing the remainder. After a time, however, it ap-

TABLE 1.

MAIN PIPE COSTS — 5-YEAR PERIOD.

Bare Costs Only — No Overheads.

Size, inches.	1920.	1921.	1922.	1923.	1924.	Averages.
6	$2.84	$2.49	$1.79	$2.49	$2.35½	$2.39½
8	3.63	2.85	2.45	2.77	3.00½	2.94
12	6.66	4.22	4.65	4.25	4.35	4.83
16	...	...	5.91	4.80	7.78	6.16

6 inch — Bare Cost (last 5 yrs.)	= $2.39½	Say,	$2.40
Overheads, etc., about 23½%	= .56¼	Overheads 25%	0.60
Actual	$2.95¾	Use	$3.00

Base Price for 1925 — $3.00 per ft. of pipe.

Note: The work done during 1924 includes straight pipe at the following average prices:

6 inch — $58.38 per ton.	12 inch — $57.75 per ton.
8 inch — 59.84 per ton.	15 inch — 57.75 per ton.

peared that too much of the cost was being borne by the department. The method was, therefore, changed to that of dividing the total cost by the net assessable frontage. This resulted in placing a greater portion of the cost on abutting owners.

I am aware at first sight the argument will probably be raised that the department should stand the whole cost from income, and when extensions are necessary they should be made from surplus reserve or from bond issue redeemed by the department as a whole. As to surplus, the argument is sound if applied to a privately operated company. A municipally operated works for very good reasons should have only sufficient surplus to tide it over the lean periods that come to any industry. A surplus in a municipal water department is always looked upon with envious eyes by other city officials and, no matter what the safeguards, there is always danger of its being abstracted for other purposes on plausible grounds, and when once gone it is hardly probable that it can ever be reclaimed.

As to the use of the depreciation fund: Theoretically, this does not belong to the water department whether privately or publicly owned. It is a reserve set up by the consumers to pay for the portions of the plant used up in their service. As such, it should be liquid. However, it is bad business to have any funds lying idle or drawing small interest. This fund may be borrowed by responsible officials for proper investment in capital expense in connection with the improvement of the plant. If so withdrawn, however, interest should be paid for it by the department as would be the case in any loan. In this case the department officials or the directors of the private company, acting for the consumers to whom the fund belongs, are acting in a dual capacity, *i. e.*, trustees of the fund for the consumers,

and directors of the water plant in need of funds. These trustees, if they so choose, can loan the money to the company at a higher rate than a bank would pay on a running account; on the other hand, they, as directors, can borrow this money from the trustees at a lower rate than they would have to pay in the market for these same funds.

This, therefore, seems a good business proposition for the consumers, who, as stated, are the owners of the depreciation fund until such time as it is required for replacement. In a municipally owned plant, of course, it matters little if this fund is used to a considerable extent to finance additions to plant, because the consumers generally are the stockholders of the company.

On the same argument concerning the danger of too much surplus, also hangs the danger in too great incomes or too high rates. In the author's opinion it is best for a municipal plant to keep rates as low as possible and resort to bond issues for payment of additions to plant, both in order to spread the cost of the improvement so far as possible over its life as well as to restrain the almost universal tendency of even the most conservative business men to be less careful of public money than of their own, and also to prevent extravagant outlay even if honestly proposed.

The handling of large public funds is often entrusted to men who never have had experience with the financial management of private business. Usually the personnel of municipal commissions changes from year to year, hence a continuing policy in conduct of work is difficult to maintain, and the qualifications of the appointees are usually based on personal or political grounds rather than on business acumen, no matter how honest the purpose.

Public bond issues, on the other hand, are usually carefully considered as an abstract proposition by independent boards of finance, composed generally of men of sound business and financial training, the whole endeavor of whom is to make a good financial showing.

Hartford's water rates are very low,— too low, perhaps,— and possibly should be raised in the near future. They are the same as were established 25 years ago: 12 cents per 100 cubic ft. for the first 3 000 cubic ft. per day, and 6 cents per 100 cubic ft. for all in excess of 3 000 cubic ft. per day. Under present conditions of labor and material costs it has been impossible to meet the cost of plant expansion directly from income, and resort has been had to bond issue for financing main-pipe extensions. One hundred thousand dollars has been so obtained each year for the past three years, and there is authority for the issue of $700 000 more in sums not exceeding $100 000 per year.

The department sets aside from income $10 000 per year for each $100 000 bond issue. The returns from the assessments are paid into a so-called revolving fund, and this will probably be allowed to accumulate until it has reached an amount of, say, $150 000, or about the amount at present paid annually for main-pipe extension work. After this, the bond issue will be stopped and the fund used to finance the work.

TABLE 2.

SUMMARY OF MAIN PIPE EXTENSIONS LAID DURING 1924.

Detail Costs.

Size, inches.	Length, feet.	LABOR Cost + 15%.		MATERIALS Cost + 10%.		TOTAL COST.		Portion Assessed.	Portion Paid by Board.
		Total.	Per ft.	Total.	Per ft.	Total	Per ft.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
6	10 018.1	$13 789.33	$1.37½	$12 759.89	$1.27½	$29 204.15	$2.91½	$24 182.72	$5 021.43
8	19 970.3	28 529.57	1.43	38 751.76	1.94	74 118.18	3.71	48 079.46	26 038.72
12	1 877.4	3 543.53	1.89	5 587.96	2.97½	10 044.64	5.35	4 989.00	5 055.64
16	1 273.4	4 789.52	3.76	6 316.68	4.96	12 216.82	9.59½	2 722.50	9 494.32
TOTALS	33 139.2	$50 651.95		$63 416.29		$125 583.79		$79 973.68	$45 610.11

Note: Col. 7 = Col. 3 + Col. 5 + 10%. Col. 8 = Col. 4 + Col. 6 + 10%.
Portion paid by Board represents 36.3% of the total cost; the estimated figure for 1924 was 37.0%.

Comparisons of Cost — Machine vs. Hand Labor.

Size, inches.	Labor, kind.	Length, feet.	LABOR.		MATERIALS.		TOTAL COST.		Remarks.
			Total.	Per ft.	Total.	Per ft.	Total.	Per ft.	
6	Machine	995.4	$1 809.01	$1.82	$1 330.29	$1.34	$3 453.23	$3.47	Rock
6	Hand	9 022.7	11 980.32	1.32½	11 429.60	1.26½	25 750.92	2.85	
8	Machine	1 413.4	2 047.21	1.45	2 875.38	2.03½	5 414.85	3.83	Rock
8	Hand	18 556.9	26 482.36	1.43	35 876.38	1.93½	68 703.33	3.70	
12	Machine	873.1	1 538.68	1.76	2 604.95	2.98½	4 557.99	5.22	
12	Hand	1 004.3	2 004.85	1.99½	2 983.01	2.97	5 486.65	5.46	
16	Machine	None	.....	...	.....	...	.....	...	
16	Hand	1 273.4	4 789.52	3.76	6 316.68	4.96	12 216.82	9.59½	
TOTALS	Machine	3 281.9	$5 394.90		$6 810.62		$13 426.07		
	Hand	29 857.3	45 257.05		56 605.67		112 157.72		

Theoretically, if $150 000 worth of work was done each year and all of it came back from assessments, this fund would be sufficient to finance the work in perpetuity. Practically, however, the amount of main-pipe work varies from year to year and — more to the point — a large proportion of the cost, as stated above, is paid for directly by department funds and does not come back in the assessment payment. This means that when it seems best to stop the bond issue and finance from the revolving fund, every increasing annual depletion will have to be made good from income. But income is increasing steadily with the growth of the city, there is an indication of lessening costs of materials and supplies, at least (for municipal labor costs rarely recede), and — more to the point — the call for extensions seems to be lessening as building operations are catching up with the demand.

A summary of the main-pipe extension work is given in the following tables which show conditions in 1924. (See Tables 1-4 inclusive.)

The total length of all pipe laid in 1924 was 54 468 linear ft., of which 8 382 ft., or 15.4 per cent., was exempted for corner lots; and 3 674 ft., or 6.7 per cent., exempted on account of street intersections.

As stated at the beginning of this paper, the method of financing is generally approved by applicants for main-pipe extensions as the most equitable way of handling this matter. It is, however, rather rigid and does not lend itself to modifications or compromising, which on the whole is a very good thing in municipal work. It leaves few bad debts, the money comes in for the work done, and every one knows just what he must do to get water to his property.

TABLE 3.

MAIN-PIPE COSTS — 1924.

Comparison of Actual and Estimated Figures.

	Actual.	Estimated.	Budget (1924).
Total Cost	$125 583.79	$129 796.95	$160 000.00
Assessments	79 973.68	81 827.00	105 000.00
Paid by Board	$45 610.11	$47 969.95	$55,000.00

Portion Paid by Board = 36.3% of the total cost — 1924.
Portion Paid by Board = 28.4% of the total cost — 1923.
Portion Paid by Board = 23.6% of the total cost — 1922.

The above work for 1924 covers the following:

Total Assessed Frontage	54 468 Feet
Exemptions	8 382 Feet, or 15.4%
Street Intersections	3 674 Feet, or 6.7%

Analysis of Amount Paid by Board — 1924.

Exemptions.	Street Intersections.	Oversize Pipe.	Connections.	Misc.
$12 319.00	$5 441.11	$23 150.00	$3 300.00*	$1 400.00*

* Estimated.

TABLE 4.

MAIN-PIPE EXTENSIONS — ASSESSMENTS.

Year.	PAID BY ABUTTERS.		PAID BY BOARD.		TOTAL COST.
	Amount.	%.	Amount.	%.	Amount.
1924	$79 973.68	63.7	$45 610.11	36.3	$125 583.79
1923	102 802.84	71.6	40 771.53	28.4	143 574.37
1922	148 952.25	76.4	45 987.58	23.6	194 939.83

Analysis of Amounts Paid by Board.

Year.	Exemptions.	Street Intersections.	Oversize Pipe.	Connections.	Misc.
1924	$12 319.00	$5 441.00	$23 150.00	$3 300.00*	$1 400.00*
1923	10 716.27	7 655.26	18 900.00	3 000.00*	500.00*
1922	15 950.69	10 685.22	15 851.67	2 500.00*	1 000.00*

* Estimated.

Total Assessed Frontage for 6-inch pipe = 18 141 ft.

Total Cost 6-inch pipe = $29 204.15

Cost per Foot of Assessed Frontage = $1.61 (including overheads).

$1.30 Bare Cost.

APPENDIX A.

AMENDED ORDINANCE CONCERNING ASSESSMENT FOR LAYING WATER MAINS.

Be it ordained by the Court of Common Council of the City of Hartford:

SECTION 1. Whenever in the opinion of the Board of Water Commissioners of the City of Hartford, public necessity and convenience require the extension of any main pipe and shall vote to make such extension, said board shall assess the cost of such extension against the land found by said board to be specially benefited thereby abutting upon the road, street or highway in which such main is to be laid, with the buildings on said land, in proportion to the frontage of said land upon such road, street or highway.

SECTION 2. Before said board shall vote to make any such extension at least ten days written notice of the proposed extension shall be given to the owner or owners of the land and buildings upon which the cost of such water mains may be assessed and of the time and place when objections to such extensions will be heard by said board, and notice thereof shall also be published twice at least in two newspapers published in the city of Hartford.

SECTION 3. Upon the final completion of the construction of such water main, said board shall give written notice thereof to the owners of the land and buildings assessed therefor and that said assessments are due and payable from the date of such notice. The amount so assessed shall be a lien upon the lands and buildings on account of which it was assessed, which lien shall commence and attach to said land and buildings from the time of the passage by said board of the vote to extend said water main, but shall not remain a lien thereon for a longer period than three months from the final completion of said work unless said board shall within that time lodge with the town clerk of the town within which such land and buildings are situated, for record, a certificate signed by the secretary or other authorized representative of said board describing the premises and the amount assessed thereon.

SECTION 4. Said board shall in no case vote to extend its main pipe in accordance herewith in any road, street or highway that has not been legally accepted by the city

or town within which such road, street or highway is located, or in any road, street or highway until the same has been rough-graded to an established grade.

SECTION 5. Said board in determining the cost of any such extension for any year shall use the average cost for the preceding five years of laying six-inch pipe in the Hartford water distribution system, provided that such average cost does not exceed the actual cost thereof.

SECTION 6. The owner of any land and buildings assessed for the cost of main pipe extensions as aforesaid may elect to pay the amount assessed as aforesaid in ten annual installments with interest on the unpaid balance thereof, provided that notice of such election shall be given to said board within thirty days after notice shall have been given of the completion of the work.

Adopted by Court of Common Council January 23, 1922, and approved by the mayor January 24, 1922. Amended March 12, 1923.

DISCUSSION.

EDWARD G. BRADBURY.* I think possibly the work which is being done in the State of Ohio under the so-called County Sewer District Law has opened a broader field in the assessment method, both for sewers and water works, than has previously been attempted or is yet being attempted elsewhere in the United States. I have found in my conversations with some of the members present that they know nothing about the law under which I am working as County Sanitary Engineer of Franklin County, Ohio, in which is located the city of Columbus. I shall, therefore, preface what I have to say by a very brief statement regarding the scope of this law, which is one of the most sweeping public utilities laws that has ever been enacted, inasmuch as it gives to the Boards of County Commissioners of the several counties of the State absolute power, without petition, without request, and without order of the State Department of Health, to create sewer districts in any part of their counties outside of municipalities, and within municipalities with the consent of the municipal council, and in those sewer districts to construct sewers or water mains as they deem necessary, and assess the entire cost according to the benefits. This power includes water mains, lateral sewers, trunk sewers, sewage disposal plants, and water supplies, all of which are being constructed and being assessed in the counties of Ohio at the present time.

One might suppose that, working outside the cities, this would be rather a small matter, but in Franklin County alone we are doing over a half million dollars' worth of work every year, and the petitions which I have in my office at the present time indicate a very large increase. In the fifteen counties where this work is being carried on there has been constructed up to this date between ten and fifteen million dollars' worth of work in the last two years.

Under proper administration this law is proving itself to be a very wise one, but it is so broad that it might readily be mishandled. I previously said petitions were not necessary under the law, nevertheless, in our county we do no work without petition, and, except in the cases of very large dis-

*County Sanitary Engineer, Columbus, Ohio.

tricts and large improvements, where it would be a physical impossibility, we require a majority petition before we do any work.

The assessment is not made until after the work is completed and the actual cost determined. The assessment includes not only the actual cost of construction, but all engineering, inspection, preliminary surveys, even interest on the bonds issued to cover the cost of construction up to the date when the first installment of assessment is collected. We also add a small percentage to cover the cost of clerical and engineering work which cannot be charged definitely to any particular job; the time of each member of the engineering force being kept very carefully and charged against each job on which he is employed, but we add this further amount to cover clerical work and such engineering work as cannot be so divided, and also to amortize the cost of equipment. The work does not cost the public at large a penny.

I have found in taking up this subject absolutely nothing in engineering literature in regard to the method of distributing assessments in proportion to benefits. I find, on studying the law on the subject and the decisions of the courts, that the measure of benefit, when the law says an assessment should be levied in proportion to benefits, is the enhancement of value of the property by reason of the construction of the improvement. In other words, it is the difference in value of the property before and after the improvement is made. Now, it is pretty hard to tell how much more a piece of property is going to sell for after an improvement is made than it did before, but you can figure how much more it ought to sell for.

I wish to call especial attention to this phase of the problem. It is a very easy matter to distribute the cost of a local service line over the abutting property, but when we construct a main sewer or main water supply line which is to be of service to perhaps ten thousand acres of land, as some of our districts exceed that area, it is quite a different proposition. In such cases, after assessing on the abutting property the estimated cost of a local line, — which we construe to be an 8-in. sewer or a 6-in. water line, just as Mr. Saville has stated, — the balance of the cost must, under the law, be distributed over the entire district in proportion to benefits. We are assessing the cost today of trunk sewers, sewage disposal plants, main water supply lines, and water supply systems, over entire districts in proportion to benefits, as we construe them, and we are assessing property a mile or more away from the improvement, where it will perhaps be five or ten years in the future before they receive any benefit. It is a very pretty problem to figure what that benefit is.

Without going into detail at all, I will say that we have worked out a method which I believe to be original. We take into consideration certain fundamental features in distributing these assessments. First, as I have stated before, that the measure of benefit is not the use but the enhancement in value of the property; second, that the ideal condition of assessment is that it should be so handled that when, at some future date,

the entire district is provided with sewers and water mains, each piece of property within the district shall have paid the same total amount per acre as of the date when service is given, subject, however, to one correction, namely, the correction for value. We hesitated some time before we used this correction and while we felt certain that a piece of land which is worth, say, $10 000 per acre, is benefited more and enhanced in value more than a piece of property of one-tenth the value, in our earlier assessments we did not use that factor, and it was adopted only after finding court decisions holding that the distribution of a benefit assessment in direct proportion to value is legal provided that the assessing official certifies that he believes it to represent a fair measure of the enhancement in value of the property by reason of the improvement.

We take into consideration, then, in figuring these assessments, certain features: first, what we call the accessibility factor. This consists of an allowance to the several portions of the district to cover future main extensions or branches for which each will at some time be assessed.

Second, we use a time factor. A piece of property which is reasonably not going to require sewerage or water supply for ten years in the future, or any other period, obviously receives less present benefit than one which requires the service now.

Third, we have the value factor. We recognize that the enhancement of value is not in direct proportion to the value of the property, and after a good deal of study have arrived at the conclusion that the ratio of the square roots of the values of the property per acre represents the actual benefits fairly.

By a series of mathematical operations the entire cost is spread over the district in accordance with these principles and the results have been very satisfactory.

I knock on wood every time I make this statement, but assessments have been levied in Franklin County on between 25 000 and 30 000 different pieces of property in the last three years, every assessment being made after publication of notice for two weeks in the daily papers, and there is yet to appear before the Board of County Commissioners one single person to protest one of these assessments. Possibly 100 out of twenty-five or thirty thousand have come to my office and asked for information as to why they were being assessed and how the assessment was distributed, and after it has been explained they have accepted it and made no further complaint.

One of our county sanitary engineers, who is something of an unconscious humorist, at a meeting held last year made the remark that the distribution of assessments was a good deal like plucking a goose, the object being to get the necessary plucks with the least squawks. And in Franklin County, we have certainly been successful in escaping the squawks.

MORRIS KNOWLES.* In addition to the very informing and ideal

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character of the data presented by the author, he has brought to our consideration a very basic and fundamental principle which ought to interest us, not only as water-works men but as those interested in public works of various kinds.

Of the decisions to which the author refers, one is from Connecticut, the state in which he himself operates, and the other is a Cincinnati decision, in Ohio, and the character of which is conveyed to us by the remarks that have just been made by Mr. Bradbury. But I think it is important for us to remember that that which is custom in one state is undoubtedly not of practice in all states of the Union, because we work under a constitutional form of government and this method of assessments for special benefits is prohibited by many state constitutions.

Perhaps one of the most important things which has been done recently in another line of work is a study which has been made by Daniel Turner, C.E., for the city of Detroit, in regard to a super-highway and transit system, extending into the outside limits of Detroit. For this he advised that it was not possible to obtain money unless there could be some form of assessment of the cost of benefits on property which would be benefited. There has therefore been passed by the Michigan Legislature a comprehensive law for the purpose of assessing the cost of those very important and expensive public works.

Recently the city of Pittsburgh, with a realization, in the construction of a subway, that about the end had been reached on raising money by bond issues, conceived the idea that such work should be paid for — to an extent, at least — by the territory which would be greatly benefited. We have had many great things done which have enhanced the value of suburban land enormously and yet they have been paid for by general taxation, either by bond issues spread over the entire city or entire county, as the case may be. It is very unfair, and yet at the present time special assessments cannot be practised in the state of Pennsylvania. For this reason an act has been introduced in the legislature — it will require another passage at the next session — which will bring before the people of the state a chance to vote upon the assessment plan for all forms of public works. This includes not only water-works but sewers, drainage, flood protection, highways, subways, transit systems, — everything that is proper to consider. What will be the result of course we do not know, but the public sentiment is running toward the idea of having a great many public works built by such a system of assessment.

I think we here should realize and know — if some of us do not know — that one of the most important contributions to this subject has been made by a man formerly prominent in the activities of this Association when he was a resident of this state, — F. Herbert Snow, now Chief Engineer of the Public Service Commission of Pennsylvania, — when he was City Engineer of Brockton, Mass., made a report upon the assessment of the cost of a comprehensive sewer and branch system for the city of Brockton.

This remains today a fundamental contribution to this subject, and has become the basis for assessment of cost for that very important public work.

I am sure that we shall all gain if items of this sort be brought to our attention and published in our Proceedings. The speaker, too, hopes that Mr. Bradbury will make that contribution for us as a result of his experience in Ohio.

As we are now on Canadian soil, perhaps an example in Canada may not be amiss, if a personal reflection may be pardoned. You will remember, of course, that even the Provinces of Canada are under the rule of Parliament and therefore under the English Common Law system, without the provisions of constitutions as we have them in the States. Some years ago — now about ten years ago, I think — there was passed by the Parliament for the Province of Ontario, an act creating a district called the Essex Board of Utilities District in the western part of the province, — opposite the city of Detroit. The purpose, as then stated—although recently enlarged to include many other things — was for building a comprehensive sewerage and water system for the seven, now eight, municipalities bordering on the Detroit River. That act gave to the engineer of the commission the duty as well as the power to state in a report the basis of the assessment for the respective communities through which water lines or comprehensive sewer or drainage lines should be built, and pumping stations erected. The exact language is not now remembered, nor the details; but in general the factors to consider were population, area, water used, the estimates for the future, and some others.

There was an appeal in one case, taken to the Ontario Railway and Municipality Board, which is the board of jurisdiction in the Province of Ontario, where municipalities desire to appeal from the acts of an administrative officer. The appeal was from an assessment of a certain trunk sewer. The method was sustained.

There is another item of vital importance to water-works men. We are always troubled with the rate question, and we are concerned because people do not understand that a large proportion of the cost of delivering water is due to something else than the payment of a coal bill or the payment of the salaries of the engineers and the firemen, the filter operators, or some others who actually turn out the water. People fail to realize that there is a large proportion of the cost paid in interest and sinking fund — that is, in annual charges on the original bill for building the works.

And if we may accomplish something by having some of that cost distributed by this method of assessments, so that in the original payment there shall be some large measure of the cost borne by the people directly affected, I feel quite sure that we will get rid of some of the difficulties of the proportionate method of assessing rates. Thus the bugaboo, — which some of us many times think is a bugaboo, — the attempt to find a service charge, will be somewhat lessened in its terror. We all realize that there is some measure of the cost which should be borne even before the water

is delivered. For my own part, I think we will find some equitable measure, and a larger measure than that which has been advanced to us by the report of our own committee. I think it is probably the fear that such is large and is not understood, which has prevented its being made as large as it ought to be. And if something helpful can be done by which some large proportion will be paid by assessment on the benefited property in the first place, then there will be less trouble in securing a reasonable service charge.

MR. BRADBURY. Mr. Knowles speaks of division of costs between municipalities. The method which I have very sketchily outlined, and which involves a great deal of detail in every individual case, has been used in our county in a number of cases to determine the proportion which is to be paid by different municipalities in the cost of a joint project. We have figured out in such cases the proportion which would be paid by property in the city of Columbus or in the suburban villages precisely as though the municipality was a part of the district, and thus determined the city's share of the cost, and in every case the municipalities, after careful study by their respective engineers, have accepted our figures without any change whatsoever.

In the only case of which I have heard where any of these county sewer assessments have gone into litigation — not in my county, but in one of the counties of the state where the same methods are used — a certain property owner protested the assessment and brought action against the county to restrain them from collecting the assessments. I think he set up every possible cause of action that he or his attorneys could think of as to why the assessments should be set aside, and among others was the argument that the assessment was not fairly and properly distributed.

Before this case came to trial, the methods used were explained to the attorneys for the plaintiff and that part of the case was immediately dropped and did not go into court. I believe that it is possible to convince anyone of the soundness and fairness of the method.

I think I should say one word as to the benefit of such a law as this. I am really surprised that no other state has adopted it. Do you realize what it means? It means that the officials in the cities can ally themselves with an agency which covers the entire surrounding territory, lay out a comprehensive water-works and sewer plan, and know that everything that is built within a reasonable radius is going to be built in accordance with such plans. We have demonstrated that it is absolutely possible to work in complete harmony with the city and carry out that precise idea. The law carries with it the provision that it is a misdemeanor for any person, firm, or corporation to construct sewers or water works, sewage-disposal works, or water supplies, outside of municipalities, in any part of the state, except under the control of the County Sanitary Department, so that a comprehensive, general plan for years in the future is assured. Expansion is encouraged, city congestion relieved, a better class of subur-

ban development results, and we have not yet discovered the objectionable features.

M. N. BAKER.* Besides the classic Brockton report that Mr. Knowles has mentioned, — a report which, as he says, deserves most careful study by anyone who is to take up such assessment problems, — there was published about that same time (early 90's) a monograph by Victor Rosewater, subsequently editor of the Omaha *Bee*. Quite recently there has been published a supplement to the *National Municipal Review* dealing with this subject of special assessments, worked up by a committee on the subject. The Washington Suburban Sanitary District, a combined water and sewer district serving a territory outside of Washington, is using an assessment plan which was worked up by Robert S. Morse, chief engineer of the district, and Abel Wolman (see *Engineering News-Record*, June 2, 1921, p. 944).

The idea of assessments for benefits carries with it a judicial passing upon the facts of each case, so the adoption in advance of an improvement and before all the facts became known and can be weighed and balanced, a plan that provides for a specified sum per front foot, is getting far away from the true conception of assessments for benefits. That is illustrated by a point brought out in the paper by Mr. Saville as to a feeling of injustice on the part of owners of corner lots where there was an acute angle.

Property is not always and necessarily benefited according to the frontage, or according to the value, as I understand it. The courts will practically never, unless there is proof of fraud or very grave injustice, go back of the decision of the commissioners who levy assessments for benefits. And that is why, just as has been mentioned in the Franklin County case, the courts have frequently said that if the commissioners declare an assessment has been made in accordance with their best judgment it thereby becomes fair and equitable and just, legally speaking. That is legal casuistry, with which we are all more or less familiar. It may be helpful or even necessary to have some such casuistry, but it does not make the thing fair. To declare in advance of a public improvement that its entire cost shall be put on the abutters, or even upon the property in a given district, is likely to get away from anything that is really just and equitable from the viewpoint of assessment for benefits. As to the Hartford plan, described by Mr. Saville in his paper, we must remember that he is only talking about water-main extensions on the basis of a 6-in. pipe.

The subject of assessment for benefits has so many modifications, but if reference will be made to the publications I have mentioned, and particularly to the Brockton study made by F. Herbert Snow thirty years ago, there will be a flood of light thrown upon the underlying principles.

MR. BRADBURY. I was in Mr. Snow's employ at the time the Brockton report was written and am quite familiar with it. While it is and has been for years a classic, it does not get to the fundamental difficulty that is en-

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countered when large sewers or large water mains are constructed as a part of a system without completing the entire system, and it is necessary to assess the actual cost as built. Mr. Snow's report treats the matter from rather a different point of view, involving rentals, fixed rates, and part payment by general tax. I believe I am correct in saying that no logical method has even been presented for solving the particular problem that I have referred to, namely, the construction of main works, and assessment of the entire cost in proportion to benefits in districts which do not and will not get immediate benefit over their entire area.

W. C. HAWLEY.* I am very glad to know that Mr. Saville takes the position which he has regarding "guaranteed revenue." My experience has been that it is frequently merely the preliminary to a lawsuit or else to the charging off of the amount of the guarantee.

I regret to differ in any way with Mr. Saville, but I can't agree with him that the replacement fund, at least in the case of a private water company, is the property of the consumers or of those served. I know that idea has obtained sometimes, but there have been two or three decisions recently where in rate cases it was claimed that the replacement fund was the property of the consumers and the court decided that it was not. See the decision of the Michigan Supreme Court in *Michigan Public Utilities Com.* v. *Michigan State Telephone Company*, P. U. R. 1925 C., p. 163.

Of course the question of depreciation is one which is involved, especially when considered in connection with the many items which make up a water-works plant. But if we will take as an illustration one unit with a short life, I think we will see the underlying principle clearly. For instance, suppose a man decides that he will go into the jitney game and he takes some of his own money, and he borrows some more, and he buys an automobile. He makes his operating expenses, upkeep, interest on the borrowed capital, and a living out of it, but at the end of four or five years his jitney is scrap. Now, if he has not earned and set aside a depreciation replacement fund he is out of business. He has no money to replace his jitney, or he has no money with which to replace that which he invested or with which to pay his debts. But if he has a replacement fund, that fund is certainly his. It does not belong to the people that he has carried in his jitney, and it would be used to replace the jitney if he continues in business. In other words, he has the right to earn from fares the money necessary to replace the loss in value of his automobile as it wears out in public service. No one could question his right to earn enough to replace tires as they wear out. That is maintenance. Depreciation is only "deferred maintenance." This principle is just as true in the case of a depreciation replacement fund accumulated over a long period of time and covering the many units of a water-works plant as it is in such a case as I have used for illustration.

This matter of extensions of mains is one of the most perplexing ones

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that the superintendent or the operator is faced with, especially in the case of a private company. Mr. Saville is lucky if he can handle his applications once a month. We get them a good deal oftener than once a week. Not so long ago I had three in one day. The difficulty is that so many people in buying lots go out into districts where water pipes have not been laid, whereas they could buy plenty of vacant lots in front of which pipe has already been laid; but they would pay more for such lots. Having bought a cheap lot on the outside of town somewhere, they think that the water pipe should be laid in front of their property, and they come in with a demand that it shall be done. I have had no occasion to do any such work as Mr. Bradbury has outlined, but we do have many applications for extensions of 50 or 100 or 500 ft., and, unfortunately, the Public Service Commission of Pennsylvania has laid down no rule, and in fact has not indicated any general principles which we can follow. The Commission of New Jersey has laid down a rule and has gone so far as to say in the case of a real estate promoter laying out a plan of lots and making those lots of large frontage, that even though the rule laid down by the commission will never return the full amount of money advanced for the extension, the amount which is not returned is a part of the cost of the development of the plan of lots just as much as the laying of sidewalks or the grading of streets.

For a good many years we asked for a return amounting to 15 per cent. of the cost of the extension before we would make it. We figured that on the average it required 15 per cent. to carry the cost of the extension only, not including any part of the investment in plant necessary to serve, — the pumping station, filter plant, reservoirs, supply mains, etc., — but merely to carry the investment in the extension itself. With the rise in prices of pipe and labor we found that the increase of those items was considerably greater than the increase in cost of service, — that is, the cost of delivering water and the consumers' costs, and it was evident that something less than 15 per cent. would carry the extension. We have been using a method which I can outline briefly.

We make an estimate of the investment necessary to make the extension, including cost of service lines and meters. The service line and meter are now furnished by the water company under rulings of the Public Service Commission. We then compute the cost of service, *i.e.*, the interest, maintenance, depreciation and taxes, say, 8½ per cent. on the investment, and add to that the cost of pumping, purifying, and delivering the amount of water which is allowed by the minimum rate. This in our case is about $1.50 per year. We also add the consumers' costs, *i.e.*, the cost of reading the meter, keeping the account, collecting, etc., which is somewhat over $3.00 per year, making a total of about $4.50 for the water and consumers' costs.

We then estimate the revenue to be received from consumers on the extension, to which we add the amount to be received for public fire protec-

tion which, in our case, is based upon an annual rate per mile of pipe. I want to point out here that this is an item which helps very materially to carry these extensions.

Having the investment, the cost of service, and the revenue, we find by proportion the amount of investment which the revenue will carry, and the difference between this amount and the total investment is the amount which the applicants are asked to advance. By equating the cost of service for N consumers to the revenue derived from the N consumers, we can determine the number, N, of consumers that will be required to carry the entire investment and the amount of investment which each consumer will carry, and thus we arrive at the amount to be returned to the applicants for each additional consumer who takes service from the extension. This method has worked out very satisfactorily, and I believe that it is a reasonable method and one which can be pretty generally applied, with perhaps some slight modifications.

Mr. Bradbury. One of the most interesting features of the Ohio law to which I have referred is that power is given to the Board to assess for maintenance from time to time, and as often as the Board of County Commissioners may see fit, and in such amount as they may find necessary. Depreciation is thus automatically provided for. Your repairs are taken care of. Money may be borrowed on certificates of indebtedness in an emergency which may arise and the cost assessed on the original property which paid for the improvement.

Speaking of the member's remark on the impossibility of any arbitrary method being entirely fair, we recognize that fact, and in each detailed assessment careful attention is given to any and all pieces of property which present unusual conditions, and the assessment is adjusted to meet such conditions. But the general rates are fixed for every part of the district on the principles that I have mentioned.

Mr. Hawley. In that connection, while I have no doubt that depreciation can be taken care of as maintenance in a comparatively small plant and in a new plant, I do not believe that the principle can be applied to a large plant or a plant that has been in existence for some years. For instance, we had to replace a pumping engine some years ago. The original investment in that engine was more than twice the amount that we were setting aside each year for depreciation. Now, if we had not had the replacement fund in cash, or available, — of course that fund is invested, but it is available for just such replacements, — we would have had a maintenance charge that would have interfered seriously with our financial operations for the year.

Mr. Bradbury. May I say in connection with that, Mr. Chairman, that that would present no difficulties whatever in our work inasmuch as our assessments are spread over a period of years and present no greater burden on the people who are paying the costs than if you put it into the water rates.

IODINE AND WATER SUPPLIES.

BY HARRY W. CLARK.*

[*Read September 9, 1925.*]

It is perhaps presumptuous in these days, when certain more or less educated people are stating that evolution is a ridiculous and impossible belief or theory, and legislatures are declaring its teaching illegal, to state anything in regard to prehistoric life that does not conform to strict Bible authority. Nevertheless, leaving aside the question of whether or no we had somewhere in our remote ancestry an animal more or less resembling an ape, it is undoubtedly true that all life on this planet was once dependent upon the sea for food and health and strength, and that we are still somewhat dependent upon the sea, or what receding seas have left upon the land in rocks and soils, for health and freedom from disease of certain types; that is, we still resort to the sea, and what has been recovered from the sea, for our well-being.

For hundreds of years swellings of the neck of peoples in certain regions have existed, and been commented upon. For several hundred years it has been the belief of groups, tribes, and nations afflicted by this enlargement, that certain waters caused it and that certain other waters would prevent or even cure it.

Sea water, ashes of sea sponges and seaweeds, extracts of sea shells, and other remedies of like origin, were used probably centuries ago to cure this disease and are, undoubtedly, still used. What the ancients believed without knowing the why or wherefore, modern science has of course proved. That is, that this swelling of the thyroid gland, known as goiter, is caused by the lack of iodine in our system and can only be cured by the use of iodine. In fact, human life had through the centuries strayed so far from the sea and sea food that only by a return to the sea and sea food, that is, the elements contained in sea water and sea food, could this affliction of goiter be adequately treated and cured.

There are regions in Europe and in this country where the enlargement of the thyroid is very prevalent, and medical observations have proved that the waters of these regions are undoubtedly low in iodine. As a matter of fact, however, we are of course not dependent upon water for this substance, as many vegetables and grains contain it in large amounts, and salt-water fish — especially certain species — are great carriers of this necessary iodine. The marine growths, seaweeds, mosses, etc., also contain it in large amounts. When somewhat more than a year ago we began to study this question of iodine in Massachusetts water supplies, we also began to determine the amount of iodine in fish and other foods, but found

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that so much work along that line had been done that we soon discontinued these food studies, although we had determined that much iodine was present in cod, mackerel, and other salt-water fish.

The iodine content of sea foods has been quite thoroughly studied by the Bureau of Fisheries of the United States Department of Commerce, and the results obtained are not surprising when one estimates, as McClendon has, that the seas of the world contain 60 billion metric tons of iodine. Two little bulletins have been recently issued by the Bureau of Fisheries, giving many results of determinations of iodine in both fresh and preserved or salted sea foods, and it is rather remarkable to note that some of this food contains as great an amount as nearly 10 000 parts of iodine per billion, or nearly 1 500 times as much in parts per billion as we have yet found in any Massachusetts water supply, the amount in the fifty or more sea fish examined by the Bureau of Fisheries varying from 390 parts in tuna fish to 9 600 parts in oyster liquor. Von Fellenberg found 900 000 parts of iodine in dried seaweed, and amounts varying from 2 to 448 parts per billion in fruits, water cress, butter, eggs, corn, wheat, etc.

These two bulletins of the Bureau of Fisheries entitled, respectively, "Iodine Content of Sea Foods" and "Iodine Content of Preserved Sea Foods," are well worthy of study. They not only give iodine determinations in fish but, as I have quoted, in many vegetables, grains, milk, eggs, meat, butter, etc.

Studies of grains and vegetables have also been quite thoroughly made by McClendon of the University of Minnesota, and others, and they have found many times as much iodine in grains, vegetables, fruits, etc., in non-goiterous as in goiterous regions. That is, wherever the soil does not contain or yield iodine to the water, grains, vegetables, and fruits are also practically free from this important aid to health.

The work in this country upon sea foods, grains, and vegetables is, moreover, but a duplicate of work done abroad; all showing the much greater iodine content of vegetables and grains in the non-goiterous regions, so called, than in goiterous regions.

In Michigan, Utah, Ohio, New Jersey, and other states very interesting studies have been made of the iodine content of water and foods, and the prevalence of goiter in regions where the waters contain iodine and in regions where they are practically free from it. Tables and diagrams have been made especially by the Michigan State Board of Health showing that where iodine was present in the drinking water in an amount equal to only half a part or less per billion the goiter rate of the drafted men in the late war was about 15 per thousand. Where the amount of iodine approached 2 parts per billion the goiter rate was only one-third this, and when the amount of iodine was approximately 3 parts per billion the goiter rate was only one-tenth the higher rate. Thousands of examinations of Michigan school children have shown that in low iodine regions 36 per cent. of these children were victims of enlarged thyroids.

In Utah, goiter rates have in certain regions run as high as 46 per cent. of the male adults examined, and 78 per cent. of the female, and examinations of children have given equally alarming data. The health commissioner of Utah — probably not from a sufficient number of examinations, however, on which to base absolute conclusions — has found that the children in parochial schools are freer from this trouble than in the public schools, and this may be due to the greater amount of fish eaten by these parochial school children. This study will be interesting when carried out more extensively and results are available from many other places. All studies have shown that the greatest incidence of the disease occurs in girls at the age of puberty and in women during pregnancy.

It is probably true that the region bordering the Atlantic seashore and running a hundred miles or more inland, and including the Southern States, is freer from goiter than any other part of the country; and that the chief goiter belt is the region surrounding the Great Lakes and the Pacific northwest, although these facts are not absolutely certain, as many further studies must be made to determine definitely the truly goiterous and nongoiterous parts of the continent.

As you know, this question of supplying iodine to water supplies has been agitated more or less for several years, and certain municipalities are adding iodine to their supplies in order that their inhabitants may take into their system daily certain amounts of this element. I am not at all sure in my own mind, however, that this is generally the most feasible and reasonable method of supplying iodine. In many places, especially in Michigan and Ohio, iodized table salt is now quite largely used, and school children are in various places given chocolate tablets containing iodine. Certain very important studies have been made of this method of application and its beneficial results positively determined. It seems to be a simpler, more direct, and more economical method than application of iodine to water supplies.

As I have said, during the past year and a half we have been studying this question in Massachusetts and have examined about 80 of the water supplies of the state.

An iodine examination is not a quick or easy thing to do. We express iodine not in parts per 100 000; not even in parts per million, but owing to the minute quantity present in most waters, we have to determine and express it in parts per billion, and in order to make this iodine determination accurately, about thirty gallons of water have to be evaporated as a preliminary step. We have gone far enough on this work to find that there is a great difference in the iodine contents of our Massachusetts waters and often a great difference in the supplies of adjoining towns. We have found, also, as might be expected, that the amount of iodine in surface waters differs with the seasons of the year, being less in winter and spring when melting snows and rains are filling ponds and reservoirs, and greater in summer when these supplies are low, are concentrated by evaporation, and the proportion of ground water entering them is greater.

It is of course evident that the geological formation has a great bearing upon the results obtained, and that iodine is obtained by water from certain soils and rocks, where other soils and rocks yield little or none. Statements have been made that the tertiary formation or deposits are richer in iodine than glacial drift formation, and this statement has a certain element of sound reasoning; and certain students of the subject have predicted that but little iodine would be found in Massachusetts waters owing to our glacial drift formation. Such is not the case, however. The average amount of iodine in the supplies examined is 2.14 parts per billion, and we have found it present in as great an amount as 6.3 parts per billion. It has been absent from one or two supplies, and the amount in our surface waters averages greater than in our ground waters. As a few of our waters contain little or no iodine and others contain comparatively large amounts, studies of the prevalence or non-prevalence of goiter in the state are being made by the State Department of Public Health to determine whether we have any particularly goiterous regions, and if the municipalities, the water supplies of which are low in iodine, are more markedly goiterous than the municipalities, the supplies of which contain much greater amounts of iodine. We believe that our goiter rate is low but will know more concerning it when this study has ended.

In conclusion, I wish to state that application of iodine to water supplies showing a lack of this element appears to me more or less wasteful, although it may be found eventually to be the most feasible way in certain instances. The ideal way of overcoming the iodine deficiency is the use of iodized salt for table use, and for use in the preparation of food, and a greater consumption of sea food. When we were dependent on evaporated sea water for all our salt we probably had iodine served to us in the most simple, economical, and efficient way and it is easy to add to the salt from our salt mines the same amount of iodine as found in sea salt. Other elements in this salt from evaporated sea water may have enhanced, and probably did enhance, our health and well-being.

THE WATER WORKS OF QUEBEC CITY.

BY J. A. TREMBLAY.*

[*Read September 10, 1925.*]

As you all know, Quebec is the oldest city on this continent, and for that reason it might be interesting to tell you briefly how, for two and a half centuries, it managed to get along without water works.

In 1608, when Samuel de Champlain founded the City of Quebec, he drank freely of the water of the St. Lawrence River, which was then comparatively pure. Today the water of the same river has to be filtered and treated by the towns using it for domestic purposes. Fortunately, nature had in store for Quebec City a much purer source of supply, the capabilities and facilities of which did not escape the eye of the engineer.

Previous to 1853, the City of Quebec had no water works. The population, which at the death of its founder, in 1635, was hardly 80 souls, slowly increased to about 4 000 in the next hundred years, doubled this number during the following score, then rapidly attained 46 000 in 1845, which figure was depleted, by epidemics, to 42 000 in 1851. Still, at this date there was no aqueduct in existence, and one may naturally wonder how a city of over 40 000 inhabitants could grow and live with no water works of any kind in its streets. However strange this may appear, the fact remains that up to 1853 Quebec was drawing its water, for domestic and fire purposes, from the rivers St. Lawrence and St. Charles, or from wells. Water was delivered in large barrels through the streets, on fixed days, by water-carriers who did a thriving business, and sold at from ten to twenty "sous" per barrel, according to the size of it. (20 *sous* is equal to $16\frac{2}{3}$ cents.) The barrel, usually painted yellow with black bands, was part of the necessary furniture of most kitchens.

With such a primitive mode of suplying water, it goes without saying that the organization for fire protection ran along the same lines. In the case of a fire, it was the duty of the water-carriers to run to the river, fill their barrels and rush back to the scene of the fire, where voluntary firemen answering the call of the church bells, would form a chain of buckets, passing the water pails from one hand to another and, finally, on to the burning building. Money used to be paid to the first carters reaching the fire with their barrels of water. Medals and rewards in cash were also offered to the deserving men. Later on, cisterns were built, of a capacity of 50 000 to 120 000 gal. of water, some of which are still in existence, to be used in case of emergency. With the advent of these wells, a Mr. Lemoine invented a fire pump operated by hand, and capable of delivering water at a pressure of about 50 lbs. per sq. in. As many as 20 men or more

* Chief Engineer, Water Works Department, Quebec City.

would line in on each of the levers to operate the pump. The first model, made out of brass, and the original pump itself are kept by the fire department as old relics.

This method of supplying water was carried on for years, until the public mind was aroused by disastrous conflagrations and deadly epidemics causing a fearful loss of life.

In 1847, the Council decided to build a water and drainage system, and Mr. George R. Baldwin, Civil Engineer, of Boston, was asked to make a report on "*Supplying the City of Quebec with Pure Water.*" The following year, the above-named gentleman submitted an extensive report on two gravity supplies, some seven miles from the city, namely, the St. Charles and Montmorency rivers, taking no heed of any nearer source; or, to quote his own words: "*The bountiful and salubrious waters of these two rivers at once discouraged any thought of abandoning them for a nearer supply by means of steam or water power, which, although it might result in a cheaper method of supplying the city, should not, to follow the recent examples of some of our large cities, on that account alone be preferred.*"

Action was deferred, and it was only in 1853 that there was completed the first supply main, an 18-in. cast-iron pipe. Its intake was located on the St. Charles River at Loretteville, at a point 7 miles from the city, and at elevation 485 above mean sea level.

Parallel with this old main, two other cast-iron conduits of 30 and 40 in. in diameter have since been laid from the same fountain head, the former in 1884, the latter in 1913.

The St. Charles River is the outlet of Lake St. Charles which has an area of 700 acres and lies in a watershed comprising an area of about 142 sq. miles of granite formation. Across the river is a solid masonry dam, 200 ft. long, 14 ft. thick at the bottom, 7 ft. 6 in. thick at the top, and 12 ft. high. Separate tunnels bring the water direct from the river to three underground basins over which stands the intake house, a solid stone and concrete building, one story high. The three conduits are provided with outside and inside metal screens and intake gates to each for opening or closing as necessary. A private telephone line connects the caretaker's residence with the water stations in the city. From the intake, the three pipes run in a southeasterly direction, crossing River Des Mères at about three miles from the dam, and River St. Charles just before entering the city. The mains are carried across the river in both cases inside of rectangular steel bridges, the larger one being 12 ft. high by 16 ft. wide and 162 ft. long. Stop-gates and suitable air and relief valves are installed on each main. Upon entering the city the 18 and 30-in. mains are used to supply the lower levels, while the 40-in. conduit feeds the upper portion of the city, the highest point being at elevation 335, or 150 ft. below the intake at Lorette. A fourth main, 10 in. in diameter, coming from a minor source, helps to supply the upper western part of the city, which formerly comprised the town of Montcalm.

There have been several breaks in the main supply pipes, attributed to different causes. For the past 8 years the repair work has been carried under my direction, and I believe that the cause of the majority of these breaks is the lack of proper bearing support. In a few cases a large stone, found underneath the pipe, was very likely the cause of the rupture.

The city covers within its limits 5 820 acres. The population is close to 120 000. The Council has the control of the administration of the water-works department. The personnel of the department consists of a civil engineer, a business manager, and about 75 men, including foremen, water-works guardians in charge of the valves on the main lines, pipe-layers, etc. The consumption, as determined by Venturi meters, averages 26 700-000 gal. per day, 1 per cent. of which is metered. The distributing pipes range from 4 to 24 in. in diameter, forming a total length of 113 miles, exclusive of the 31 miles of supply pipes. Pressure is good all over the city, ranging from 75 to 110 lbs. per sq. in. in the lower levels, and 50 to 90 lbs. up town. There are 13 000 domestic services and 1 100 hydrants. The total cost of our water-works system is $4 900 000. Its valuation today, considering the increased cost of material and labor, is figured at $6 500 000. Interest and sinking fund amount to $318 500, while the cost of maintenance is 1 per cent., or $49 000 per year.

Discussion.

Frank E. Winsor.* I would like to ask Mr. Tremblay how deep he lays his pipe for frost protection.

Mr. Tremblay. The depth of the burying of the pipes varies between 5, 6 and 7 ft.

President Taylor. How deep does the frost go up here? About 4 or 5 ft.?

Mr. Tremblay. Yes, and sometimes more. In the streets where the electric cars run, frost will go down as much as 7 ft. In some places there is only 3½ or 4 ft. cover over the pipes and yet we are not troubled with freezing, likely due to extra good circulation in the pipe; but in general we lay them 6 to 7 ft. deep.

George C. Ham.† I would like to ask Mr. Tremblay about the condition of the original main. I understand it was laid in 1853, which is over 70 years ago. It might be interesting to know what the interior condition is and whether it has ever had to be blown.

Mr. Tremblay. That first main is in very good condition. The cast iron seems better than what you get today, judging from what we hear of the foundry people who get it. Of course the capacity of the pipe has diminished to some extent, — that is, I would say about 25 per cent., — due to incrustation; but on account of our water being soft the incrustation of the pipes does not usually go over half an inch. That old main is still in service.

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† General Manager, Naugatuck Water Company, Naugatuck, Conn.

M. N. BAKER.* I would like to have Mr. Tremblay answer two questions: One is the subject of epidemics. It would be interesting to know what those epidemics were before they had their present water supply. And the other is, what protection there is to the supply mains laid across the bridges in this cold climate.

MR. TREMBLAY. The epidemics referred to were typhus and cholera.

MR. BAKER. Not typhoid?

MR. TREMBLAY. No; typhus. By "protection," you mean protection from frost?

MR. BAKER. From freezing.

MR. TREMBLAY. These three pipes are carried across the river just inside a rectangular steel bridge.

MR. BAKER. No protection?

MR. TREMBLAY. No protection, no heating. The pipes never freeze; there is quite a good velocity in them. We never have had any trouble with freezing during the winter.

MR. BAKER. Have you any idea what the velocity would be?

MR. TREMBLAY. The velocity in the larger main, 40-in., would be, I should imagine, between 2 and 2½ ft. per second; and it would be much more in the smaller mains. It would be about 4 ft. per sec. in the 30-in. and probably 2½ to 3 ft. in the 18-in. The two are connected together and carry the same pressure.

GEORGE F. MERRILL.† I would like to ask if a special arrangement was made to keep a separate flow in the different mains so that each one would have circulation; that is, as they supply different parts of the city, I suppose it must be that they each have separate sections.

MR. TREMBLAY. Yes; the mains are so arranged that their flow could be kept separate, but to suit actual conditions they are working in pairs. The 18 and 30-in. mains supply the lower sections of the city only, both pipes coming into the city independently, but connecting together in the distributing system feeding the lower levels only; while the 40-in. main goes right through the lower town to the top of the hill, and from there feeds the whole of the upper town with the help of the 10-in. main which feeds mostly the western part of that section.

PRESIDENT TAYLOR. As I remember Quebec, there is a great difference in the elevation of the upper or new part of the city, and the old — something like 100 ft. or more — so that the two systems are necessarily carried separate.

MR. TREMBLAY. There is 300 ft. difference in elevation between the highest point uptown and the lowest point of the lower town.

PRESIDENT TAYLOR. So that a system which would give ample pressure on the upper part of the system would be too much for any reasonable mains in the lower part.

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* Associate Editor, *Engineering News-Record*.
† Greenfield, Mass.

MR. TREMBLAY. It would. The 40-in. main comes into the city with a pressure of 195 lbs. per sq. in., but by the time it gets uptown it carries only about 110 lbs. Pressures in that section of the city range from 50 to 90 lbs.

THE FILTRATION WORKS OF THE CITY OF MONTREAL.

BY FREDERICK E. FIELD.*

[*Read September 9, 1925.*]

The sole purpose of this paper is to give the members of the New England Water Works Association a general description of the municipal filtration works of the city of Montreal, Quebec, Canada, prior to their proposed visit on September 12, 1925.

It will therefore be necessary to include considerable information that has been previously presented before engineering societies or published in engineering journals.

Water Supply.

The water used by the citizens of Montreal is obtained from the St. Lawrence River and is distributed to the consumers by two independent corporations. The Montreal Water Power Co., a private corporation, with a shore intake opposite the city of Verdun, has filtered its water supply since June, 1912.

The municipal water works of the city of Montreal has both a shore and a midstream intake located about two miles above the Lachine Rapids of the St. Lawrence River. From an entrance gate chamber, which receives the supply from both intakes, a concrete conduit, $8\frac{1}{2}$ ft. in diameter, conveys the water a distance of 5 miles to the filtration plant and the old low level pumping station. The capacity of this conduit is approximately 90 m.g.d. (Imperial).

In addition to this conduit supply, the city has during the last few years completed the enlargement of the Montreal Aqueduct Canal. The entrance of this canal is an imposing structure comprising a concrete bridge and head gates. There are three head gates, each 57 ft. wide and 18 ft. high. The gates are counterweighted and operated by winches located in towers which are connected by elevated platforms.

The water cross-section of the aqueduct canal is approximately 150 ft. wide and 15 ft. deep.

The canal is about 27 000 ft. long and terminates at the old wheel house, built in 1870, just below the site of the pumping station and the filtration works. Below the wheel house and spillway, is the tail race which extends for about 3 000 ft. to the St. Lawrence River. There is about 18 to 20 ft. head available at the old wheel house which will undoubtedly be utilized for power development.

The concrete conduit and the several intakes from the aqueduct canal provide the city of Montreal with an adequate supply of water for both present and future needs.

* Filtration Engineer of the Montreal Water Board.

Need of Purification.

For many years the excessive number of cases and deaths from typhoid fever indicated the necessity for improving the quality of the water used for domestic purposes.

During the late fall and winter of 1909–1910 a severe epidemic of typhoid fever prevailed in Montreal which occasioned 203 deaths between October 1, 1909, and March 1, 1910.

The necessity for prompt action was recognized and on February 8, 1910, the treatment of the municipal water supply by hypochlorite of lime was started.

On April 4, 1910, Messrs. Hering and Fuller of New York City were engaged to report on the best means of securing an improved water supply. Their report recommending filtration, submitted July 2, 1910, was adopted and they were engaged to prepare plans and specifications and supervise the construction of filtration works for the city of Montreal.

General Description.

In 1910 the average daily output from the municipal water-works plant was 38 m.g. (Imp.), and Messrs. Hering and Fuller designed the filtration works for a normal daily output of 50 m.g. with provision for future extensions to provide an ultimate capacity of 150 m.g.d.

The most unusual departure from general practice was the combining of rapid sand filters with slow sand filters, or the "double filtration," to permit of adequate purification without the use of chemicals, except for the sterilization of the filtered water by chlorine treatment.

Furthermore, the slow sand or final filters were designed to permit of the sand being cleaned by Blaisdell washing machines.

The St. Lawrence River water is conveyed to the filtration works by means of a 9-ft. concrete conduit branching off from the 8½-ft. conduit, previously mentioned as bringing the river water from the intakes to the old low level pumping station.

Filtration Pumping Station.

This station, about 80 feet by 60 feet in plan, includes basement and ground floor.

The basement is divided into two equal parts by the raw water suction conduit and the raw water discharge conduit, which are placed one above the other.

The direct connected motor-driven centrifugal low lift pumps are located on both sides of the central conduits in such manner as to obtain their supply from the lower conduit and discharge into the upper conduit with a minimum of piping connections, and against a head of approximately 18 feet.

On the north side of the station four of the pumps are also similarly connected to a filtered water-suction conduit and a filtered water discharge conduit. This enables these pumps to be utilized for pumping the filtered water to the old low level pumping station. This double pumping has been a necessity up to the present time, but when the new low level pumping station is in service, the filtered water will not require pumping but will flow by gravity to the suctions of the high lift pumps in the new pumping station.

The filtration pumping station includes the following equipment.

4 Raw water pumps,	unit capacity	17 500 Imp. gal. per min.
2 Raw water pumps,	unit capacity	11 600 Imp. gal. per min.
2 Raw water pumps,	unit capacity	5 800 Imp. gal. per min.
2 Wash water pumps,	unit capacity	1 300 Imp. gal. per min.
1 Sump pump,	unit capacity	330 Imp. gal. per min.
1 Sump pump,	unit capacity	150 Imp. gal. per min.
1 Rotary blower,	unit capacity	5 000 cu. ft. air per min.

The ground floor of the building contains a well-equipped laboratory and office on the north side, and repair shop and storage room on the south side.

The pumping station, similar to all other buildings, has walls of red brick and cinder concrete roofs covered with green tiles.

All buildings are heated by electricity.

Pre-Filters.

The pre-filters, located east of and adjoining the pumping station, are supported by groined arches above the roof of the filtered water basin. There are 16 pre-filters arranged 8 on each side of a central operating gallery. Each filter unit has a central gutter into which the 16 concrete wash troughs empty.

The strainer and air system is made up of cast-iron headers and 2-inch cast-iron pipe laterals with brass orifices spaced on 6-inch centers.

The filtering material consists of 15 in. of gravel, graded into four sizes and placed in corresponding layers, and 30 in. of sand having an effective size of 0.50 mm. to 0.60 mm. and a uniformity coefficient of 1.65.

The net sand area is 1 200 sq. ft. and the normal unit capacity of each filter is $3\frac{1}{4}$ m.g.d. (Imp.).

Longitudinally through the center of the operating gallery are two concrete conduits placed one upon the other. The upper, or raw water conduit, receives its supply from the raw water pumps in the filtration pumping station. The lower, or pre-filter effluent conduit, takes the discharge from the pre-filters and conveys it to the final filters.

These two conduits are connected to the pre-filters by cast-iron piping with hydraulic controlling valves.

All these valves and also the valves for air, wash water, and drainage are controlled from 16 operating tables on the gallery floor. For controlling the rate of filtration, rate controllers of the Earl type are provided.

The wash-water tank, having a capacity of 104 000 Imp. gal., is located in an adjacent building.

A Winslow water level gage located on the gallery floor enables the filter operator to ascertain the depth of water in the tank at the beginning and end of each filter wash.

Final Filters.

There are 16 final filters located directly east of and adjoining the pre-filters.

The arrangement of gallery conduits, piping, and controllers is similar to that of the pre-filters and needs no further description.

The final filters are each 55 ft. by 340 ft., inside measurements, with the short dimension adjoining the gallery to better accommodate the use of the Blaisdell washing machines.

The filters are covered by groined arches supported by piers on 19-ft. centers.

The under-drainage system consists of two half-round 8-in. tile laterals in each bay, which discharge into a central main collector $2\frac{1}{2}$ ft. in diameter, extending the entire length of the filter below the floor level.

The filtering material consists of 12 in. of gravel, graded into four sizes, and 27 in. of sand having an effective size of 0.25 mm. to 0.35 mm. and a uniformity coefficient of 2.10.

The filter washing is done by two Blaisdell washing machines, which run on longitudinal tracks in each bay. A transfer table in the gallery permits of the washing machines being transferred as desired.

These washing machines operate with the normal depth of water above the sand.

They rake and wash the sand to any desired depth, leave the sand clean and uniform, and pump away to the drain all dirt and foreign matter accumulated since the previous washing.

All this is accomplished at one operation and with one man operating the machine.

The time required to clean one filter unit, having a net sand surface of 16 000 sq. ft., is 10 hours.

Filtered Water Basin.

The filtered water basin is constructed of concrete, having inverted groined arches for the floor and groined arches for the roof. It is about 439 by 232 feet in plan and has a capacity of $6\frac{1}{4}$ m.g. (Imp.).

Filtration Contracts.

The cost of construction, based on final estimates and payments, is as follows:

Pumping machinery, blower and cranes	$48 550.41
Final filters and appurtenances	674 436.20
Pre-filters and filtered water basin	498 782.30
Buildings	160 076.00
Interior painting	1 815.42
Exterior electrical conduit system	6 029.80
Underground electrical cables	12 627.04
Transformer building	6 000.00
Total cost	$1 408 317.17
Cost per m.g.d. (Imp.) rated capacity	$28 000

Operation Records.

The filtration plant was first placed in service in April, 1918, at which date the consumption had increased to over 60 m.g.d. (Imp.) or approximately 20 per cent. in excess of the designed capacity of the plant.

The filters were therefore operated at full capacity from the start, and the deficiency of the plant's output was made up of sterilized raw water.

The raw water is a mixture in varying proportions of the St. Lawrence and Ottawa rivers.

The St. Lawrence River water is rather hard, having an average alkalinity of about 95 parts per million and average permanent hardness of about 20 parts per million.

The Ottawa River water is very soft, having an average alkalinity of about 10 parts per million and a very small amount of permanent hardness.

Characteristics of Raw Water — 1924.

Per cent. of St. Lawrence River water	46.4
Alkalinity of St. Lawrence River water	57 parts per mil.
Color of St. Lawrence River water	33 parts per mil.
Turbidity of St. Lawrence River water	12 parts per mil.
Chlorine, natural combined	3.4 parts per mil.
Sulphides and chlorides of calcium and magnesium	8.7 parts per mil.
Magnesium as carbonate	4.4 parts per mil.
Total solids	105.4 parts per mil.

TABLE 1.

Analysis of Influent and Effluent — 1924.

	Average Daily Consumption.			Chlorine p.p.m.	Turbidity.			Bacteria Count, Agar — 96 hours — 20 C.				Bacterial Efficiency.		
	Filt.	Raw.	Treated.		Raw.	Pre-filt.	Final filt.	Raw.	Pre-filt.	Final filt.	Treated water.	Pre-filt. from raw water.	Final filt. from pre-filt. eff.	Final filt. from raw water.
Jan.	62.3	6.6	68.9	0.49	9	3	2	5 700	1 950	150	10	61	92	95
Feb.	82.8	8.8	71.6	0.40	6	2	2	4 370	1 310	25	4	69	98	98
Mar.	62.8	8.8	68.7	0.45	6	2	2	8 410	3 840	293	10	51	92	96
Apr.	61.8	7.6	69.4	0.63	19	7	3	12 040	4 530	333	22	65	92	96
May	62.2	5.9	68.1	0.67	20	3	2	4 450	727	48	19	64	93	98
June	62.6	7.8	70.4	0.64	11	2	2	2 010	376	29	12	80	92	98
July	46.0	27.9	73.9	0.87	12	2	2	1 640	357	50	20	76	86	96
Aug.	39.3	34.8	74.1	0.96	6	2	2	1 380	470	200	15	63	58	82
Sept.	62.9	12.0	74.9	0.39	11	3	2	2 650	648	18	15	78	97	98
Oct.	49.8	24.2	74.0	0.68	10	3	2	4 500	1 500	34	20	66	97	98
Nov.	63.7	8.2	71.9	0.52	13	4	2	6 500	2 300	250	22	62	89	95
Dec.	62.5	9.8	72.3	0.51	10	3	2	6 600	2 400	530	150	62	78	91
Ave.	58.2	13.4	71.6	0.51	11	3	2	5 020	1 700	163	27	66	89	95

Note: Filter-plant operation was suspended during parts of July, August, September, and October on account of new construction work.

TABLE 2.

COMBINED PRE-FILTER RECORD — 1924.

	Ave. period of service in hours.	Ave. rate m.g.d. (Imp.)	Ave. per cent. wash water.
Jan.	59	3.23	0.31
Feb.	63	3.26	0.27
Mar.	63	3.19	0.28
Apr.	22	3.13	0.77
May	11	2.99	1.28
June	26	3.03	0.54
July	79	3.03	0.19
Aug.	100	3.15	0.16
Sept.	100	2.99	0.14
Oct.	157	3.02	0.14
Nov.	62	2.98	0.27
Dec.	58	3.02	0.27
Ave.	66	3.09	0.39

TABLE 3.

COMBINED FINAL FILTER RECORD — 1924.

Filter No.	Total washes.	Ave. wash hours.	Ave. period of service, days.	Ave. rate m.g.d. (Imp.)	Total wash water used, m.g. (Imp.)
1	12	11	26	4.05	1.277
2	12	11	28	4.05	1.254
3	13	10	25	4.05	1.173
4	11	9	30	4.06	1.001
5	15	9	23	4.06	1.485
6	12	10	27	4.06	1.117
7	12	10	28	4.05	1.196
8	13	10	25	4.05	1.266
9	12	9	28	4.05	1.139
10	14	11	24	4.05	1.403
11	13	10	25	4.05	1.312
12	13	11	25	4.03	1.369
13	13	11	25	4.05	1.345
14	14	10	25	4.06	1.473
15	12	10	26	4.04	1.116
16	11	10	28	4.05	1.139
Total.....	202	..	..	..	20.065
Ave.....	12.5	10	26	4.05	1.254

Total quantity of water filtered in 1924 = 21 372 m.g.

Per cent. of wash water:

Pre-filters.....0.39

Final filters.....0.09

Total.....0.48

Operating Staff.

The operating staff for 1924 consisted of 21 men, classified as follows:

1 Chemist and bacteriologist.
1 Filter plant supervisor.
1 Clerk.
4 Electrical operators.
4 Pump attendants.
4 Filter operators.
2 Washing machine operators.
1 Master mechanic.
1 Sterilization plant attendant.
1 Laboratory assistant.
1 Laborer.

The electrical operators, pump attendants, and filter operators work on the basis of three shifts of eight hours.

The cost of the above staff, based on the 21 372 m.g. filtered in 1924, was $1.51 per m.g. (Imp.), equivalent to $1.26 per m.g. (U. S.)

TABLE 4.
Distribution of Cost — 1924.

Division.	Operation.	Maintenance and repairs.	Total Cost.	Cost per m.g.	
				Imperial.	U. S.
Supervision	$3 120.06	$549.00	$3 669.06	$0.17	$0.14
Pump. station	10 630.16	1 324.11	11 954.27	0.56	0.48
Pre-filters	4 976.08	1 117.78	6 093.86	0.28	0.23
Final filters	3 106.42	1 937.34	5 043.76	0.24	0.19
Laboratory	3 181.10	402.27	3 583.37	0.17	0.14
Sterilization	15 039.71	1 270.10	16 309.81	0.76	0.64
Elect. current	32 800.00	....	32 800.00	1.53	1.27
Bldgs. and grounds	....	1 414.15	1 414.15	0.07	0.06
Totals:	$72 853.53	$8 014.75	$80 868.28	$3.78	$3.15

The cost of sterilization includes $12 500 for hypochlorite of lime, which is approximately $0.60 per m.g. (Imp.) of water filtered.

The present necessity of pumping the filtered water for delivery to the high lift pumps accounts for 50 per cent. of the electric current.

Making this deduction for a more proper comparison of costs with other filter plants, we obtain a cost of $3.00 per m.g. (Imp.), or $2.50 per m.g. (U. S.) for all operating expenses of the Montreal Filtration Works for the year 1924.

The details of the operation for the year 1924 are shown in Tables 1–4.

Extensions of Pumping and Filtration Works.

The need of extensions to and improvements of the water-works system of Montreal has been recognized for many years, but it was not until

1920 that a separate organization, the Montreal Water Board, was established to study the needs, prepare plans and specifications, and supervise the construction of new works.

Up to the present time, much of the work of the Water Board, such as the completion of the aqueduct canal, the construction of bridges across the same, the extension of large force and distribution mains, etc., is not closely related to the subject-matter of this paper and will not be described in detail.

We will, however, briefly describe the new pumping station and the new filtered water basin.

New Pumping Station.

The new pumping station is located on the filtration side of the aqueduct canal and north of the final filters. The structure includes a central control building, a pump building, an electric building, and a wing building, the latter containing a machine shop on the ground floor and storerooms on the two upper floors.

The superstructure is of brick, with concrete roof covered by red tiles.

The front portion of the first two floors of the control building is an entrance hall. Back of this, on the ground floor, is the local service electrical apparatus; and above, on the second floor, is the central control room. This room includes the switchboard and electric operating table, the hydraulic operating table and the Venturi meter registers for the pumping units. This room affords an unrestricted view of the entire pump room.

On the third floor of this building are the offices of the Montreal Water Board.

The pump room is arranged for 6 motor-driven centrifugal pumps having a unit capacity of 30 m.g.d. against a total head of 250 feet. All suction and discharge piping is located in the basement.

Each pump receives its supply through a 42-in. pipe directly connected to the new filtered water basin, located behind the pumping station.

After passing the Venturi meter, the 36-in. discharge pipe divides into two 36-in. branches, each of which is connected to a 72-in. riveted steel discharge header. The flow through each of these branches is controlled by Larner Johnson valves, thus permitting either or both of the 72-in. headers to be in service.

The electric building contains, on two floors, all high tension and low tension electric equipment required for the operation of the 6 pumping units.

The two 72-in. discharge headers extend from the pumping station to a separate structure called the distribution control building. Here each of the headers divides into two 48-in. force mains controlled by motor-operated gate valves. By-pass connections are provided to enable water from any header to be discharged to the city through any one or all of the 48-in. force mains.

All control valves on the discharge mains, in both the pumping station and the distribution control building, are operated either locally or at the hydraulic operating table in the central control room.

As previously stated, the present pumping station is arranged for 6 pumping units, each having a capacity of 30 m.g.d.

The designs contemplate a possible future extension to provide for a capacity of 360 m.g.d. This may be accomplished by constructing, on the south side of the central control building, a pump building, electric building, and wing building similar to these already built on the north side of the control building.

When this is carried out, the pumping station will be symmetrical with respect to the central control building. There will be 12 pumping units having a unit capacity of 30 m.g.d., and there will be three 72-in. discharge headers which will divide at the distribution control building and thus provide six 48-in. force mains to convey the water supply to the city of Montreal.

New Filtered Water Basin.

The new filtered water basin recently constructed and placed in service is located between the pumping station and the old filtered water basin of the filtration works, to which it is connected.

This new basin has a floor area of about 5 acres and a capacity of about 20 m.g. (Imp.) with 15 ft. depth of water.

The floor, walls, columns, and roof are of reinforced concrete. As a protection during cold weather the roof slab is covered with earth to the depth of $2\frac{1}{2}$ ft.

Along the side of the basin parallel with the pumping station, the floor is depressed to a depth of $5\frac{1}{2}$ ft. and a width of 25 ft. This depressed bay is divided longitudinally by a wall extending from floor to roof with openings opposite each of the twelve pump suctions controlled by 5 ft. x 5 ft. sluice gates.

Between this dividing wall and the outside wall of the basin, cross weir walls are so constructed as to provide a separate suction chamber for each pumping unit. The top of these weir walls is 8 ft. above the floor of the main basin and $13\frac{1}{2}$ ft. above the floor of the depressed bay, thus leaving an unrestricted conduit 8 ft. high and 12 ft. wide above the top of the weir walls.

From the north end of this intake bay a conduit 9 ft. in diameter leads to an emergency intake gate chamber in the bank of the aqueduct canal. Here the flow is controlled by a 5 ft. x 7 ft. motor-operated sluice gate.

In case of necessity the supply from the filters can be shut off by closing the 5 ft. x 5 ft. sluice gates in the dividing wall of the depressed bay, and water from the aqueduct canal brought to the pumps by opening the sluice gate in the emergency gate chamber. This water will be sterilized by chlorine apparatus installed in the emergency gate house.

The weir walls in the intake bay also afford a means of access to the

suction chamber of any pump without interfering with the operation of the other pumping units. This is accomplished by lowering the water level in the main basin below the top of the weir walls, and closing the 5 ft. x 5 ft. sluice gate to the suction chamber to be entered. Then by emptying this suction chamber by a drainage system and removing a cast-iron cover in the roof of the intake bay, the sluice gate, drainage gate valve, and intake screen are available for inspection, painting, or repairs.

Park Features.

The filtration works and new pumping station occupy part of an 80-acre tract of comparatively level ground between the aqueduct canal and St. Joseph Street, city of Verdun.

As almost all of the works, with the exception of the superstructures of the various buildings, are below ground level or covered with earth as a protection during cold weather, the site is capable of development into a very attractive park, and such work has already been done about the new pumping station.

Here the grounds have been graded and seeded, roads and paths constructed, which, together with two lagoons, each 50 ft. by 130 ft., having water sprays, and several flower beds, make the setting of the pumping station very attractive.

Plans for future work of this character include the extension of roads and paths, the planting of trees and shrubs, and a park lighting system.

New Filtration Works.

Preliminary studies have been made for the long-needed extensions to the filtration works and, as appropriations have recently become available, construction work will be under way during the season of 1926.

It is proposed to immediately construct extensions for a capacity of 100 m.g.d., but to so plan the work as to permit of extensions for an ultimate capacity of 300 m.g.d.

The new filtration works will differ from the existing plant in several particulars.

(1) It will be a gravity plant, taking its supply from the aqueduct canal and delivering its effluent into the filtered water basin below the existing pre-filters.

(2) It will be a standard rapid sand, or mechanical filtration plant, instead of having double filtration.

The plans contemplate alum mixing basins, coagulation basins and filters, with the usual appurtenant structures; all to be located directly south of the existing plant.

There will be a single operating gallery with filters and coagulation basins, on both sides.

The coagulation basins will be of the continuous flow type, with the water having a straight flow the entire length of the basins to the filter inlets.

The filters will each have a net sand surface of 2 160 sq. ft., giving a rated unit capacity of 5 m.g.d. (Imp.), or 6 m.g.d. (U. S.), a somewhat larger unit than is usually constructed.

The filters will be divided longitudinally by a central double conduit, the upper being the raw and waste-water conduit and the lower the filtered and wash-water conduit.

The present studies contemplate a strainer system made up of 4-in. pipe laterals, each 15 ft. long, having a direct connection with the central filtered water and wash-water conduit. The filter material includes 21 in. of gravel and 30 in. of sand.

On the north end of the gallery will be located the administration building, with the superintendent's office, etc., on the ground floor, and the chemical and bacteriological laboratories on the floor above.

At the south end of the gallery of the immediate construction, consisting of 20 filters, will be located the building containing the wash-water tanks and wash-water pumping equipment.

The arrangement is such that from the superintendent's office there will be an uninterrupted view of the entire length of the filter gallery which, when the plant is extended for the ultimate capacity of 300 m.g.d., will be about 1 200 feet.

The filters and coagulation basins will have concrete roof slabs covered with earth as a protection against the cold of winter weather. The roofs of the filters are raised above the floor of the operating gallery to give sufficient head room to permit walking from the operating gallery along the top of the center conduit of each filter to the passage running longitudinally the length of the plant between the coagulation basins and the filters. This cross wall over the center of each filter affords a clear view of the entire filter during washing or other operations.

The superstructures of the various buildings will be of brick, with concrete roofs covered with tile to harmonize with the existing plant.

All buildings will be heated by electricity.

Studies are not sufficiently advanced to permit of a more detailed description at this time, but the above statements explain the general features of the proposed works.

PERIOD OF STORAGE AND MICROÖRGANISMS IN RESERVOIRS.

BY ROBERT SPURR WESTON.*

This short paper simply records observations regarding the relation between the period of storage of water in a reservoir and the average number of microörganisms growing therein.

The period of storage in a reservoir is expressed sometimes as "Days of Storage," sometimes as "Storage Ratio." This latter is the storage capacity of the reservoir divided by the mean annual run-off. Thus a reservoir which stores the mean annual run-off stores the water 365 days, or has a storage ratio of 1.00. Again, a reservoir having a storage ratio of 0.33 stores the mean annual run-off for 4 months. Because there is no such thing as the orderly displacement of stored water by entering water; because wind and temperature produce mixing currents and because the run-off itself varies with the season and the years, these figures represent average conditions only. Nevertheless, they are of great utility for the study and planning of reservoirs for water supply.

INDEX OF FREQUENCY.

The relation between the normal period of storage and the frequency of occurrence of organisms did not escape the attention of the classical writer in this field — the late George C. Whipple. He compares the period of storage, in days, with what he termed the "index of frequency," *viz.*:

"It was assumed that when the organisms were less than 500 per c.c., they would cause no trouble; between 500 and 1 000 per c.c., little trouble; between 1 000 and 2 000, noticeable trouble; between 2 000 and 3 000, decided trouble, and that above 3 000 the trouble would be serious. From the analyses the per cents. of the time when the organisms were present within these limits were ascertained. These were then weighted as follows and added together: For numbers between 500 and 1 000, one-half the per cent.; for numbers between 1 000 and 2 000, the per cent. as computed; for numbers between 2 000 and 3 000, twice the per cent.; and for numbers above 3 000, three times the per cent. The above was based on organisms of all kinds, disregarding genera.

"An index of 50 would mean that the growth of organisms was noticeable half of the time, or that if they were present for less than half the time they were more troublesome during the time they were present.

"The maximum figure for the index of frequency, possible by this method of computation, would be 300, but it is rare indeed that any natural water gives an index of more than 100, and in the best stored waters the index is generally less than 10. The minimum of course is 0."

* Weston and Sampson, Consulting Engineers, Boston, Mass.

This index of frequency refers to organisms which cause trouble, not to all organisms; and the following figures given by Whipple for 47 lakes which he studied, show the relation between this index and the normal period of storage.

TABLE 1.

RELATION TO PERIOD OF STORAGE.

Storage ratio.	Period, days.	NUMBER OF LAKES.		
		Index 0 — 25.	Index 25 — 50.	Index 50 — 100.
0 — .13	0 — 50	1	1	1
.14 — .27	50 — 100	2	1	1
.28 — .54	100 — 200	7	2	3
.55 — 1.36	200 — 500	8	4	7
1.37 and over	500 and over	2	5	2
	Total.	20	13	14

These figures do not lead to very definite conclusions. They show that three-quarters of the lakes which have a low index of frequency store water from 100 to 500 days. On the other hand, 10 of 14 reservoirs which store water for the same period have a high index of frequency (50-100).

NEW JERSEY STUDIES.

In connection with studies made for the North Jersey District Water Supply Commission, we were interested to compare the relation between the storage ratio in several lakes and reservoirs in the highlands of New Jersey and the average numbers of microscopic organisms (not the index of frequency) found therein. The following table shows these relations.

TABLE 2.

RELATION BETWEEN STORAGE RATIO AND MICROÖRGANISMS OF VARIOUS RESERVOIRS IN THE WANAQUE AND PEQUANNOCK DRAINAGE AREA, RESPECTIVELY.

Body of water.	Drainage area, square miles.	Capacity m.g.	Yearly inflow, m.g.	Storage ratio.	Micro-organisms, standard units per c.c.
Sterling Lake	5.1	3 586	2 360	1.52	93
Greenwood Lake	27.1	14 079	11 354	1.24	188
Canistear Reservoir	5.6	2 407	2 625	0.92	366
Clinton Reservoir	10.5	3 518	4 935	0.71	558
Pequannock, total	63.7	11 808	29 890	0.39	518
Oak Ridge Reservoir	27.3	3 982	12 800	0.31	569
Echo Lake	4.6	612	3 982	0.28	579
Forge Pond	14.7	7.5	7 090	0.011	652

Comparing similar data relating to the Croton system of reservoirs for the year 1907 (Whipple), we get the results given in the following table.

TABLE 3.
CROTON SYSTEM.

Lake or reservoir.	Storage ratio.	Microscopic Organisms per c.c.	
		Year.	Summer months.
Lake Gilead	1.60	56	94
Lake Mahopac	1.53	447	227
West Branch Reservoir	1.47	1 084	1 010
Muscoot Reservoir	1.26	1 069	1 239
Titicus Reservoir	0.86	1 798	1 271
Lake Gleneida	0.67	219	348
Kirk Lake	0.54	1 230	1 132
Middle Branch Reservoir	0.53	1 732	2 048
Boyd's Corner Reservoir	0.35	284	444
Sodom Reservoir	0.18	807	799

While all of these reservoirs are not independent, and are fed in some cases from other reservoirs rather than from streams, and while the number of organisms in the two smallest reservoirs are comparatively low, the data show that the apparent effect of storage is to reduce microscopic growths.

If we compare the reservoirs which store for more-than-one, one, and less-than-one seasonal overturn, we get the following.

TABLE 4.

Period of storage.	Average storage ratio.	Average Microörganisms per c.c.	
		Year.	Summer months.
More-than-one overturn	1.46	539	642
One overturn	0.72	1 008	810
Less-than-one overturn	0.53	1 013	1 106

From the above the advantage of long storage may be deduced.

Consider now the independent reservoirs of the Massachusetts Metropolitan system. Here we compare the weekly or bi-weekly observations for the years 1912 to 1916, with the results given in the following table.

TABLE 5.
MASSACHUSETTS METROPOLITAN SYSTEM.

Reservoir.	Storage ratio.	Microörganisms, Standard units per c.c.	
		Surface.	Bottom.
Wachusett	1.46	645	371
Whitehall	.79	349	...
Hopkinton	.75	354	...
Ashland	.48	456	...
Cochituate	.32	3 258	4 909

Apparently the Wachusett is somewhat out of line with the general rule. This discrepancy is explained easily by its comparatively recent construction. Some treated sewage reaches Lake Cochituate.

In General.

It seems quite generally true that in the uplands of the northeastern United States the reservoirs suffer from growths of microscopic organisms, in inverse ratio to their storage ratios.

The reservoirs which suffer most are those having storage ratios below 0.70, especially those having ratios below 0.40. The reservoirs freest from growths are those which store waters for a period including both the spring and the fall overturns of the reservoir water.

It is the writer's hope that the data in this paper will lead engineers to design reservoirs of ample size biologically as well as hydraulically. Other things being equal, those surface waters are best which are gathered quickly and are stored for an ample period in a clean reservoir.

A SCORE SYSTEM FOR GRADING WATER SUPPLIES ACCORDING TO SANITARY CONDITIONS.

BY E. SHERMAN CHASE.*

[*Read September 10, 1925.*]

The water-works engineer has generally hesitated to rate the sanitary condition of water supplies according to any definite quantitative scale, due to the complicated factors and many uncertainties which enter into the problem. The following paper is an attempt to present a system of scoring for the sanitary condition of water supplies, which will serve as a means for expressing this condition in quantitative terms. It must be pointed out that such terms are of necessity relative only and cannot be absolute. Primarily any score system must be used largely as an aid to judgment.

Precedents for scoring rather intangible qualities are fairly numerous. Health Departments establish scores for dairies and for the quality of milk supplies. In the field of water supply quality the Health Department of New York State has used a score system for several years. Bacterial index standards have been established by the U. S. Treasury Department for water supplies used on interstate carriers. The Board of Fire Underwriters has a system for scoring the fire hazards of any municipality and, incidentally, scores the adequacy of the water-works system from the standpoint of fire protection.

Water-supply scores based upon bacterial standards alone, valuable though they may be, do not take into account all the factors which tend to make up the sanitary condition of water supplies. Analytical results are largely history, but also serve as a basis for predictions as to future quality of a supply. Such results also show the effectiveness of sanitary safeguards and of purification methods. They may not, however, afford any clue as to potential hazards surrounding the sources of supply or the methods employed in its purification and distribution. For this purpose the physical features connected with the sources and development of the supply must be known.

The score system presented in this paper is in the main a modification of the system used in the New York State Health Department as developed by the author and Mr. Theodore Horton, formerly Chief Engineer of that Department.† The system herewith presented modifies and expands the original system in several respects.

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* Sanitary Engineer, of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

† 1915 Annual Report of the New York State Department of Health, Vol. iii, p. 175.

Classification of Water Supplies.

For purposes of the score system water supplies are divided into two main classes, — surface supplies and ground water supplies. The surface supply group contains a special sub-group consisting of supplies taken from the Great Lakes system and from the Mississippi and St. Lawrence rivers. The ground water supply group also contains a sub-group consisting of supplies taken from wells over 500 ft. deep.

Scoring Factors.

In dealing with water supplies from the sanitary standpoint, there are three major factors to be considered: first, the pollution hazards; second, the protective measures; and third, the quality condition.

The first factor, pollution hazards, is made up of those conditions, active or potential, which bring about or tend to bring about pollution of the water supply, such as resident population on the watershed or the direct discharge of sewage into sources of supply. The second factor, protective measures, consists of those barriers, either natural or artificial, which prevent or tend to prevent pollution in the original source of supply reaching the consumer. Natural storage and filtration are examples of protective measures. The third factor, quality condition, is determined by the results of analyses and by those physical attributes perceptible to the senses. Of these, bacterial content and taste and odor are examples.

Score System.

In view of the simplicity resulting from the use of a percentage scale, the score system presented in this paper is based on a range of values from 0 to 100 — the higher the score the better the sanitary condition of the supply. The 100 scale is divided into three parts of 50, 20, and 30, which are assigned to the factors for pollution hazards, protective measures, and quality condition, respectively. These values are assigned when the factor under consideration represents perfect or nearly perfect conditions. The higher value assigned the first factor is justified by the distinct advantage of supplies from unpolluted sources over those requiring purification. Protective measures are assigned a lower value than quality condition, due to the fact that the existence of such measures is no assurance of continuously effective purification, whereas analytical results, if of sufficient scope, measure the final end point, — the quality of the supply furnished. In other words, the proof of the water is in the drinking. It should be noted that the sum of perfect scores for the first and third factors alone, does not equal 100. This is due to the fact that under conditions as they exist no supply, in the absence of barriers against chance pollution, can be considered perfect. A supply taken directly from a pure mountain stream may be polluted by hunters or other visitors to an otherwise uninhabited watershed, and analytical results fail to show the presence of such intermittent and potentially dangerous contamination.

Outline of Score System.

The number and diversity of minor factors affecting the sanitary condition of water supplies render it impossible to discuss at length each of these minor factors in a brief paper. Consequently, the following outline has been prepared, to summarize the factors involved, together with tentative score values for each factor.

Surface Supplies.

(Main Group.)

I. Pollution Hazards:	
Score for no hazard	50
Hazards connected with sources of supply:	
1. Population on watershed (p = population per sq. mile of watershed):	
a. Contributing indirect pollution	$-2\sqrt{p}$
b. Contributing direct pollution (sewage)	$-8\sqrt{p}$
c. Where sewage is diverted from watershed consider population decreased by one-half the population whose sewage is thus diverted.	
2. Highways and railroads (per linear mile per sq. mile of watershed)	−1
3. Lumbering, labor camps, hunting, etc.:	
a. Lumbering, labor camps, etc.	−2
b. Hunting, picnicking, etc.	−1
4. Animal pollution:	
a. Direct	−4
b. Indirect	−2
5. Industrial wastes	−5
6. Leaky intake, suction main or gravity main passing through sewage-polluted water	−25
Hazards Connected with Storage and Distribution of Supply.	
7. Fishing, boating, ice-cutting, bathing, etc., on reservoirs:	
a. Fishing and boating	−2
b. Ice-cutting:	
Ice house at reservoir	−2
Ice house away from reservoir	−2
c. Bathing	−5
8. Accessible distribution reservoirs:	
a. Open and unprotected	−5
b. Open but protected by locked fence, etc.	−2
9. Inadequate protection against polluted water leaking into pure water reservoirs, *e.g.*, double-storage tanks, one part for safe and other for unsafe water; leaky raw water conduits passing through clear water basins, etc.	−5

10. Cross-connections with polluted supplies ..... −10
11. Dual water-supply systems, one from a safe source and the other, for emergency use, from a sewage-polluted source ..... −10

II. Protective Measures:

Total score not to exceed 20

1. Sewage and industrial wastes treatment, divide score for direct pollution hazard and industrial wastes sewage according to extent of treatment, as follows:
   a. Sedimentation, divide by 2.
   b. Complete treatment without disinfection, divide by 3.
   c. Complete treatment with disinfection, divide by 4.
2. Proper sanitary regulation, patrol, and enforcement ... 4
3. Ownership of watershed, 100% 5
   (For less than 100%, pro-rate according to area owned.)
4. Storage (minimum):
   a. One month or more 10
   b. Two weeks 5
5. Water Purification:
   a. Chlorination 10
   b. Pressure mechanical filters:
      With coagulation basin 10
      Without coagulation basin 5
   c. Gravity mechanical filters 15
   d. Slow sand filters 15
   e. Copper sulphate treatment, aeration, etc., for algae .. 5

(For combinations of the above purification methods add individual scores, total credited not to exceed 20.)

6. Covered distributing reservoirs 10
   Fenced distributing reservoirs 5
7. Adequate pressure and storage 10
   (Rendering emergency or auxiliary supplies unnecessary.)

Penalties for Failure or Inadequacy of Protective Measures.

1. Improper operation of sewage and industrial wastes treatment plants — allow no credit.
2. Lax enforcement of sanitary regulations, improper or inadequate regulations, irregular patrol or none .... −2 to −4
3. Short circuits in storage reservoirs ..... −5
4. Improper operation of purification plants: (Not to exceed −15).
   a. Inadequate dosage of chlorine ..... −10
   b. Intermittent operation of chlorination apparatus, absence of duplicate equipment, etc. ..... −5
   c. No coagulant with mechanical filters ..... −10
   d. Exhaustion of chemicals or chemicals of poor quality −5

e. Filters in poor condition..... −5
f. Combustible buildings housing essential equipment.. −5

III. Quality Condition:

Total score not to exceed..... 30

Turbidity:
Clear..... 2
0 to 5 p.p.m..... 1
Over 5 p.p.m..... 0

Color:
Colorless..... 2
0 to 10 p.p.m..... 1
Over 10 p.p.m..... 0

Odor:
None..... 2

Taste:
None..... 2

Hardness:
Under 50 p.p.m..... 1

Corrosiveness:
None..... 1

Iron and manganese:
Less than 0.5 p.p.m..... 1

Total bacterial counts on agar at 37° C.— 24 hrs.:
Less than 100 per c.c..... 5
Over 100 per c.c..... 0

B. coli type:
Absent in 100% of 10 c.c. inoculations..... 20

(Present in part of 10 c.c. inoculations, pro rate according to per cent. of samples positive.)

SURFACE SUPPLIES.

(Sub-group: Great Lakes, Mississippi and St. Lawrence rivers.)

I. Pollution Hazards:

Score for no hazard..... 50

Population within two weeks' time of flow above intake in case of rivers, or within 30 miles of intake in case of Great Lakes (p = population 1 000)

a. Contributing indirect pollution..... $-2\sqrt{p}$
b. Contributing direct pollution..... $-8\sqrt{p}$

(Other pollution hazards score, where applicable, the same as for main group.)

II. Protective Measures:

Same as for main group.

III. Quality Condition:

Same as for main group.

GROUND WATER SUPPLIES.

(Main group: depth less than 500 ft.)

I. Pollution Hazards:	
Score for no hazard	50
1. Population (p = population):	
a. Between radius of 1 000 ft. and 3 000 ft.	$-2\sqrt{p}$
b. Between radius of 500 ft. and 1 000 ft.	$-5\sqrt{p}$
c. Within radius of 500 ft.	$-10\sqrt{p}$
2. Sewers, cesspools, etc., within 500 ft.	−10
3. Improperly protected top	−5
4. Leaky casings	−5
5. Connections with polluted surface water	−10
6. Flooding of vicinity by sewage-polluted surface water	−5
7. Distribution hazards:	
The same as for surface supplies.	
II. Protective Measures:	
Total score not to exceed	20
1. Depth and kind of strata penetrated:	
Sand under 20 ft. in depth	5
Sand over 20 ft. in depth	15
Sand and gravel under 20 ft. in depth	3
Sand and gravel over 20 ft. in depth	10
Seamy rock and limestone	0
2. Purification methods:	
Credits and penalties the same as for surface supplies.	
III. Quality Condition:	
The same as for surface supplies.	

GROUND WATER SUPPLIES.

(Sub-group; depth more than 500 ft.)

I. Pollution Hazards:	
Score for no hazard	50
1. Population (p = population):	
a. Within a radius of 3 000 ft.	− p
(Other pollution hazards the same as for main group.)	
II. Protective Measures:	
Total score not to exceed	20
1. Overlying soil:	
Same as for main group.	
2. Purification methods:	
Credits and penalties the same as for surface supplies.	
III. Quality Condition:	
The same as for surface supplies.	

Conclusion.

The foregoing outline constitutes the author's personal judgment as to the values which should be given the different factors entering into the appraisal of the sanitary condition of water supplies. There are, of course, opportunities for differences of opinion in the matter of ascribing values to intangible attributes. It is believed, however, that discussion and the advancement of other opinions should make it possible to establish a rating scale which would be generally applicable with a fair degree of justice. It is believed that if water-works officials would balance the sanitary liabilities and assets of the water supplies in their charge according to the above or similar score system they would discover unexpected and unappreciated hazards. With progressive water-works men a defect exposed is a defect remedied.

Discussion.

Charles W. Sherman.* I believe that Mr. Chase has given us a very valuable suggestion in this paper.

It must be obvious to anyone who gives a little thought to this matter, and who has a chance to look over these figures and consider how they would apply to his own case, that rather an intimate personal knowledge of many of the details of the water-works system, the supply system and the distribution system, is necessary, fully as much if not more than the results of analyses and tests, to apply this or any similar scoring system to a supply.

An abstract discussion of the relative importance or unimportance of certain items is the basis of the adoption of the figures presented, and their definite application to particular supplies which are known to be very good, or pretty good, or not very good, may give very surprising results, and perhaps to indicate that the basis of scoring is wrong, or perhaps to indicate that the supplies are really better or poorer than we think they are.

Beekman C. Little.† I am wondering if the basis which Mr. Chase has laid out in his paper is applicable for any one city, — for instance, New Bedford. If Mr. Taylor made up his score on the basis Mr. Chase has given, would he reach the same result that Mr. Sherman would reach if he went over to New Bedford and figured up the score. Is it so fixed that we could all arrive at the same result for the same city, or is it like the income tax, where you can get a good many different results by having different men try it?

Mr. Sherman. I think it must be admitted that there is a possibility and perhaps a probability, of a difference. It is my belief, after studying the paper and discussing it with Mr. Chase, that the difference probably would not be great in the aggregate. The scheme is, in general, similar to that of the National Board of Fire Underwriters for rating their fire risks, except this one is on a 100 per cent. basis where you can form some better

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† Superintendent, Water Works, Rochester, N. Y.

mental gage of what it would be as compared with perfection than with a more or less arbitrary scale where you have 732, and you don't know what that means. It is very probable that the individual items might be scored somewhat differently by two different individuals applying the same system. It seems to me, and I am sure Mr. Chase was convinced, that the probability would be that different individuals would reach pretty nearly the same final score.

The matter of individual judgment necessarily enters into any scoring of this kind. I presume that it would rarely be the case that two inspectors of the fire underwriters, going to the same city and studying the fire hazard, would reach exactly the same efficiency scoring for such cases, but they find it nearly enough applicable to produce reasonably comparable results — and results which they feel are really significant. And I think the probability is that the same condition will exist in this case. One inspector or sanitary engineer studying the hazards which may reach a total of 50 points, might rate a certain supply at, say, 42, and another might call it 40 or 43. On the protective measures, with a total of 20, one inspector might rate a supply at 18 and another at 16. My impression is that differences of that kind are probably something that we may expect of reasonably trained inspectors. But they certainly must apply the element of judgment, based upon acquaintance with the conditions, in order to score fairly.

J. FREDERICK JACKSON.* I do not know that I have anything of value to add to the discussion, that has not already been contributed.

This matter of the scoring of water supplies to get some standard by which ratings of different supplies could be established that would be of assistance to the State Departments of Health, in maintaining proper supervision, has been given a lot of thought, both by members of this Association and members of the Sanitary Divisions of the American Society of Civil Engineers and the American Public Health Association. The difficulty has been, as I think is apparent from the paper that Mr. Sherman has just read, to get a standard which is not so complex as to discourage its use by State Health Departments and those water-works officials who are particularly interested in the subject. There are so many different factors that enter into the problem and have to be weighted, that most of the men who have had this scoring under consideration have become discouraged, and concluded that no easily enforced standard is possible. Up to the presentation of the paper the subject has been somewhat neglected, since Mr. Horton's proposed method was presented several years ago before the American Public Health Association. I think, however, that it is possible to establish some measure or standard, and I think that Mr. Chase is to be commended for still persisting in working along these lines. I believe that ultimately we are going to get a standard that is easily administered.

In any scoring of supplies the sanitary survey, which includes an intimate knowledge of the watershed, its topography, character, and location

* Consulting Engineer, New Haven, Conn.

of buildings, number of persons, cattle, etc., has been given greatest prominence. The character of the water itself — physically, chemically, and bacterially — probably should next receive consideration and, finally, treatment of the water; whether by aeration, sedimentation, filtration or sterilization. To correctly evaluate all of these factors for any given supply requires a great deal of time and labor and, in the final analysis, the exercise of most experienced judgment. Involved formulae are not, I am afraid, going to be helpful because their complexity will discourage their general use. The problem must be stripped of all unessentials and the standard be of such a nature that, given the essentials, the supply under consideration naturally falls into a given group.

ARTHUR D. WESTON.* Any attempt made by me with a view to scoring a public water supply has been somewhat unsatisfactory, chiefly because of the many factors involved and the almost impossible task of properly weighting these various factors. I have in mind one watershed of a surface water supply to which the average person, scoring in accordance with Mr. Chase's factors, would grant a satisfactory score. Its watershed is entirely free from population but has a very rapid run-off, and certain areas, when examined, were found to be dressed with manure into which had been mixed the contents of privies, these privies having been carefully removed from the watershed in order to prevent pollution.

I was pleased to note that Mr. Chase suggests no special score to be considered a "standard." So far as public health work is concerned, I believe that the word "standard" should be forgotten, as our aim should be to always strive to improve conditions. I do think that the subject of scoring is worthy of a great deal of consideration because, when tried, it will naturally bring conditions to the attention of all parties interested which previously, because of long association with such conditions, had ceased to appear as a menace to the purity of the supply. I believe that a committee of the New England Water Works Association to work along the lines that Mr. Chase started, taking perhaps his results as a foundation, could bring something before the Association which would be of great value and which would act as an incentive for all water-works officials to attempt to score their own supplies. Such an attempt at scoring would naturally tend to improve conditions relating to such supplies.

M. N. BAKER.† The scheme is certainly a worthy one, and I have before wondered that more had not been done along the line suggested. Some of these things come slowly, as this example shows, for Mr. Chase and Mr. Horton proposed something of the sort a good many years ago; but little, if any, use of their original plan has yet been made. It is difficult indeed to get water-works and other municipal departments to adopt worthy plans devised for the purpose of getting comparative municipal statistics.

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* Principal Assistant Engineer, Massachusetts Department of Public Health.
† Associate Editor, *Engineering News-Record*.

Now that a grading plan has again been brought to the attention of the public, and now that we have so may well-organized State Boards of Health with engineering departments, as compared to what there were even ten years ago, we may hope to see the plan taken up by at least some of the State Boards of Health. I take it that there would be less difficulty if the scoring were done by one man or set of men for a whole state than if superintendents or others connected with municipal plants, or with private, individual plants, attempted to make the scoring, although it is very desirable, I think, that the individual superintendents should see what they can make out of it as regards their own sources of supply.

An attempt to correlate the scoring of the sanitary quality of the water supplies with the vital statistics of the community might be made, particularly with the typhoid death rate.

MR. SHERMAN. The authority resulting from the action of a committee helps in getting a thing of this kind started, and the investigations of the committee would probably have the effect of interesting a larger number of our members in it than merely seeing the paper in the JOURNAL.

I therefore move that the Executive Committee be authorized to appoint a standing committee on a system of sanitary scoring of water supplies.

(The motion was duly seconded and carried.)

A FINENESS MODULUS FOR FILTER SANDS.

BY RICHARD G. TYLER.*

[*Read September 11, 1925.*]

The purpose with which the present investigation was undertaken was to endeavor to find, if possible, a more definite and a more accurate method of designating the size of filter sands, since the method of Hazen's, at present in use, seems in need of modification. Mr. Hazen stated when he published his results, that "It is not probable that the above data regarding a sand include all the important points to be known, or that further study will not modify or change the method of calculation; but, in the absence of better methods, their use allows extremely valuable approximate calculations, which would otherwise be almost impossible."[1] His method has rendered, and is still rendering, helpful service, but it is desirable to be able to predict, with greater accuracy, the probable behavior of a filter sand than can be done as yet.

Perhaps the most important later addition to the knowledge of this subject, is found in the work of Slichter[2] and King.[3] They propose the use of an effective size or diameter of sand grain as determined by measuring the time required to pass a known quantity of air through a definite volume of the air-dried sand under specified conditions of pressure. The apparatus used for this determination is known as the King Aspirator. The results obtained by this method will be given at a later point in this paper. While it has advantages over Hazen's method, it requires special apparatus which is more difficult to use and is found less often in testing laboratories. A method based upon a study of the mechanical analysis of the sand has such obvious advantages that the present investigation was undertaken.

The particular criticism of Hazen's method is that it fixes only two points on the graph representing the sieve analysis of a given sand. A number of such graphs may be drawn through these two points and vary considerably as to amounts of coarse and fine materials, porosity, irregularity of grains, etc., which items undoubtedly affect the transmission capacity of the sand, or the amount of water that can be transmitted through a cylinder of unit length and cross-section under a unit head in unit time. (Slichter). A factor similar to the fineness modulus of Professor Duff A. Abrams ("The fineness modulus of an aggregate is the sum of the percentages given by the sieve analysis, as retained on each sieve, divided by 100.") would appear to have the advantage, when used in conjunction with the effective size, of defining the sand more in detail and of fixing more than the two points mentioned.[4]

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It was found impossible to use the data of other experimenters for a check against the speaker's tests, since complete analyses of the sands were not available.

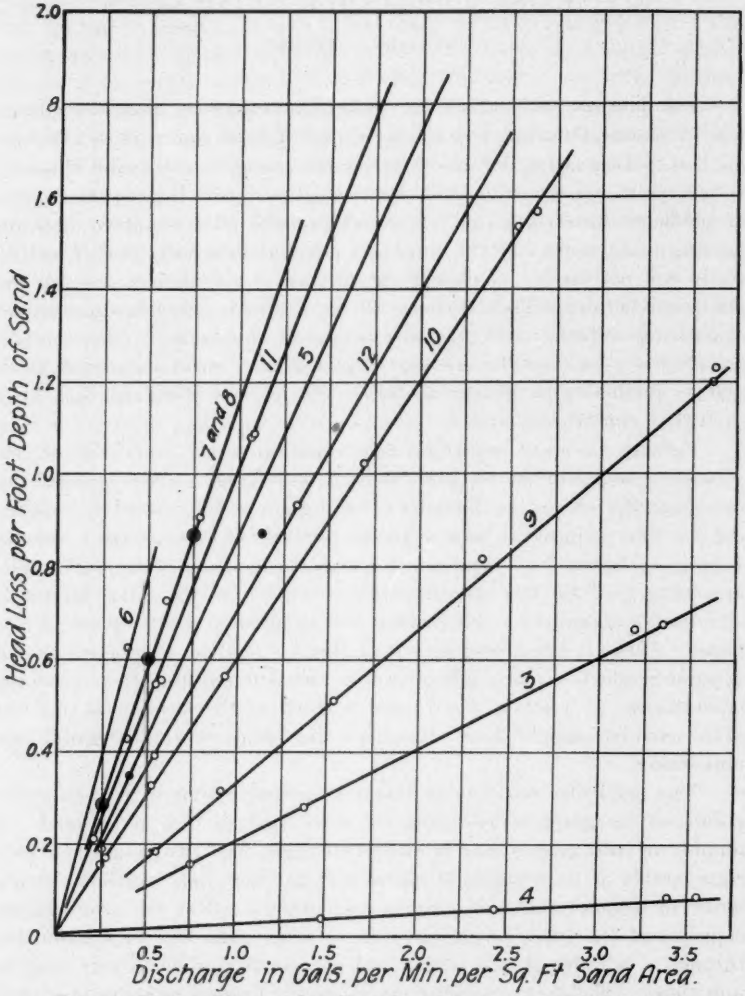

FIG. 1.— LOSS OF HEAD IN ONE FOOT DEPTH OF SAND UNDER VARYING HEADS AND DISCHARGES.

Ten samples of sand, the analyses of which are given in Table 1, were used, the samples being, with two exceptions, artificial mixtures of sand obtained locally from the Boston Sand & Gravel Company. Sand No. 3 is Standard Ottawa sand, while sand No. 12 was taken from the upper foot

of a vertical section of filter No. 2 at the Cambridge Filter Plant, Cambridge, Mass. This sand was thoroughly washed and all mud balls removed before testing.

The procedure used in the preliminary experiments (not reported here) consisted of placing the sand in a vessel as shown in Fig. 4, to a depth of 18 in. on about 2 in. of gravel. Metal cloth prevented the sand from working down appreciably into the coarser gravel. The apparatus is similar to that used by Hazen, except that varying heads of water could be used, the head being read by means of a hook-gage. The pressures at two points in the sand bed, 12 in. apart vertically, were read from the water columns in glass tubes as shown. Water was admitted above, the flow being held constant, while the discharge was regulated by a valve on the outlet. This apparatus was so large that the preparation of samples was onerous, and the removal of air from the voids was never entirely satisfactory. After a number of tests had been run, both the apparatus and the results were discarded and somewhat smaller but similar apparatus was employed, using a glass container so that the conditions of flow in the sand could be observed. The sample required was smaller, the pressures being read at points within the sand bed and 0.4 ft. apart vertically. The water was admitted at the bottom and discharged at the top.

TABLE 1.

SIEVE ANALYSIS OF SANDS.

Sand No.	Per Cent. Passing Each Sieve.					
	100	48	28	14	8	4
3	0.0	0.0	0.0	100.0	100.0	100.0
4	0.0	0.0	0.0	0.0	40.0	90.0
5	0.5	10.5	32.0	50.0	73.0	95.0
6	3.0	35.5	52.0	61.0	77.0	95.5
7	0.7	17.7	62.2	89.7	97.7	99.7
8	3.5	20.0	48.0	79.5	91.5	98.5
9	0.0	1.5	38.0	85.0	100.0	100.0
10	0.0	5.0	33.0	88.0	100.0	100.0
11	0.0	0.0	55.0	65.0	81.0	100.0
12	0.0	1.0	67.0	100.0	100.0	100.0

It was found to be impossible to remove all the air from the voids by stirring or by forcing the water through from the bottom for reasonable time intervals. Boiling the sand for about thirty minutes, with slight stirring, was found to be a more satisfactory method. The sand was then placed and tamped under water. Care was used to prevent stratification, which was the principal difficulty encountered under this method. Tests were run at different head losses and the discharges determined, time being allowed for the pressure to become equalized throughout the sand before readings were taken.

The results obtained are shown graphically in Fig. 1. The figures designate the sample number of the sand used. The points fall fairly well on straight lines passing through the origin, as one would expect from Darcy's or Hazen's formulas. The data are for a temperature of 72.0° F.

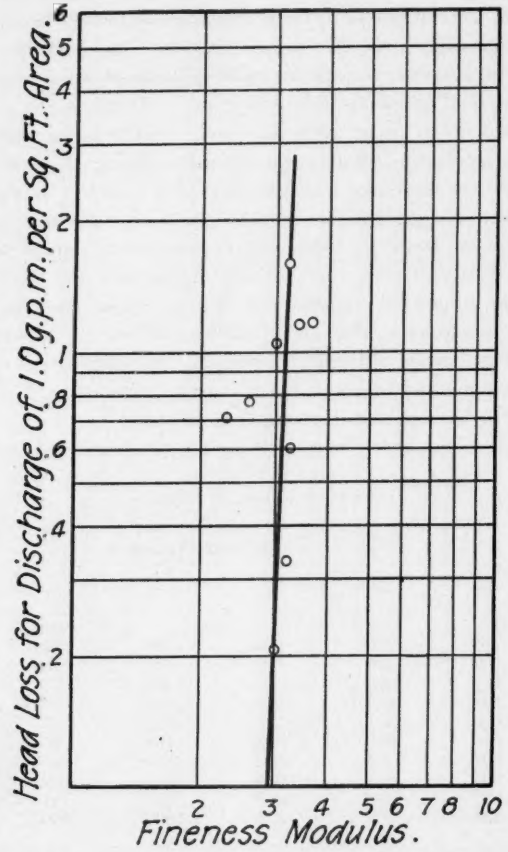

FIG. 2.— RELATIONSHIP OF LOSS IN HEAD TO FINENESS MODULUS.

It was found that the fineness modulus gave little or no indication of the head loss or transmission capacity of the sand. Fig. 2 shows this by the almost vertical line which gives the general relationship of fineness modulus to head loss. It seemed plausible, however, that the head loss should vary more as a function of the total superficial area of sand grains than as the fineness modulus, the speaker having in mind the Abrams-Edwards controversy in regard to fineness modulus *vs.* surface area of sand for concrete aggregates. The task of determining the actual surface areas

of a given sand is laborious, but Talbot's[5] "Surface Modulus," which is proportional to the total surface area of the aggregate and can therefore be used for it in these computations, is determined easily and was used. With the sieve series used (Tyler sieves used by Abrams) this surface modulus may be found from the formula

$$S = P_1 + \frac{P_2}{2} + \frac{P_3}{4} + \frac{P_4}{8} + \frac{P_5}{16} + \frac{P_6}{32} + \frac{P_7}{64}.$$

Where P_1 = percentage passing through the No. 100 sieve P_2, P_3, etc. = percentage between 100-48, 48-28, etc.

This assumes that there is little material passing the No. 200, which is the case with filter sands and the test sands used.

The surface moduli of the various sands are shown in Table 2. Fig. 3 shows the relationship of surface modulus to head loss. The head loss for Fig. 3 is the loss in head for a discharge of 1 gal. per minute per sq. ft. of cross-sectional area through a cylinder of sand 1 ft. in length. This is taken from Fig. 1. The equation for Fig. 3 may be written

$$h = 0.00099\ S^{2.25}\ Q$$

where h = head loss per foot depth of sand bed
S = surface modulus
Q = discharge in gallons per minute per sq. ft. area of sand bed.

TABLE 2.

CHARACTERISTICS OF SANDS TESTED.

Sand No.	Effective size.	Uniformity coefficient.	Porosity.	Fineness modulus. *	Surface modulus (Talbot).	Velocity, meters per day.		
						Hazen C = 500.	Surface modulus.	Observed.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3	0.616	1.43	35.8	3.00	12.50	53.2	82.0	58.5
4	1.390	2.25	40.6	1.30	4.22	33.0	58.5	58.5
5	0.283	5.58	31.4	2.61	15.33	47.7	31.0	58.5
6	0.168	6.43	...	3.24	26.11	30.7	56.2	58.5
7	0.215	2.71	38.1	3.68	24.35	36.3	63.9	58.5
8	0.193	3.98	33.7	3.41	23.68	29.3	59.7	58.5
9	0.350	2.31	38.5	3.24	16.68	27.9	95.0	58.5
10	0.334	2.45	39.3	3.26	17.12	46.0	55.9	58.5
11	0.337	2.46	33.3	3.01	16.59	78.4	31.6	58.5
12	0.328	1.67	...	3.68	21.12	51.7	74.9	58.5
	Average error					19.06	14.23	...
	Average error in per cent					32.6	24.3	...

* The values in this column are computed for data passing each sieve rather than that retained on each, as in Abrams' work. It is not felt that it is necessary for comparative purposes to follow Abrams' method of calculation in this instance, since it is probable that a different series of sieves will have to be used for filter sands than was used in Abrams' investigations and in this paper. The present series leaves the diameter of much of the material rather undetermined, and it is believed that the series proposed by the American Water Works Association would be preferable and would give, of course, a different fineness modulus. To convert the above data to Abrams' basis, subtract the values given from 6.0.

It is apparent from a comparison of Figs. 2 and 3 that the surface modulus gives a better indication of the transmission capacity of a sand than does the fineness modulus. The points, however, do not fall as closely on a straight line as might be desired. To see how this method compares with Hazen's formula as a means whereby the transmission capacities of sands may be predicted, values for velocity of flow in meters per day were

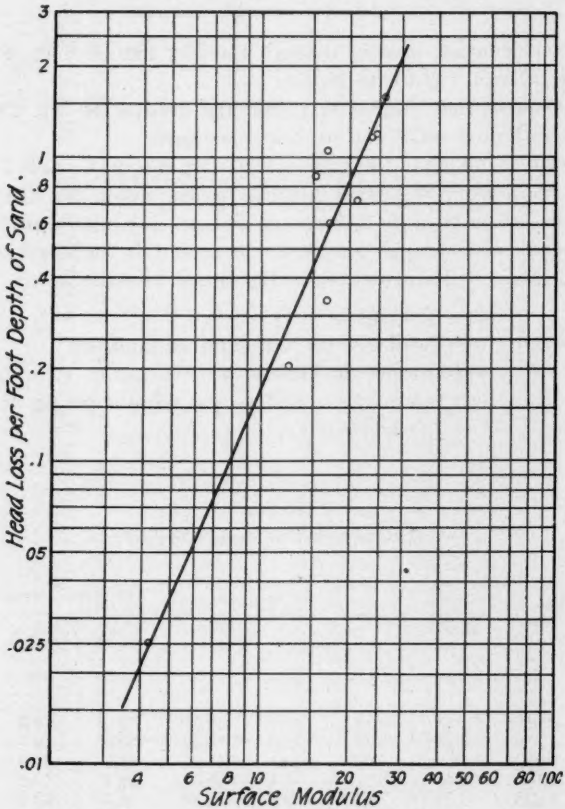

FIG. 3.— RELATIONSHIP OF LOSS IN HEAD TO SURFACE MODULUS.

computed both by his formula, using C = 500, and from the curve in Fig. 3 for the known surface moduli. These data are given in Table 2, from which we see that the average error by the Hazen formula is 32.6 per cent., while for the surface modulus method it is 24.3 per cent.

This would indicate, in the speaker's judgment, that the surface modulus of a filter sand gives a better method for describing sands than that used at present and one as easily applicable, and that further investigations along this line would be desirable.

The present series of tests is being continued with improved apparatus, this paper being only in the nature of a report of progress already made. Until more tests have been made the speaker would suggest that the graphs and coefficients given here should be used with caution, for while they will give satisfactory results in determining the relative values of transmission constants, head losses, etc., absolute values for the probable discharge of a

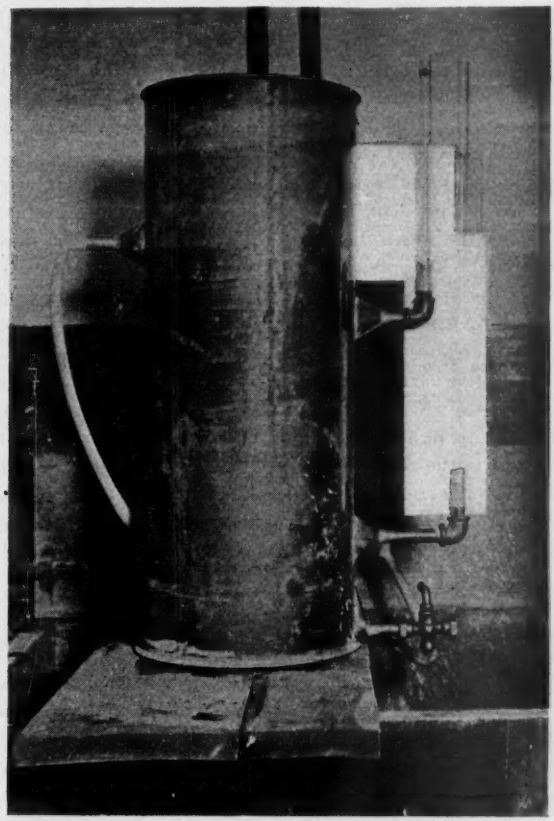

FIG. 4.— APPARATUS USED IN PRELIMINARY TESTS.

given filter may be very much in error, due to difference in operation of the filter from that of the test apparatus, and the fact that filter sands are clogged by floc and bacterial growths, while these tests were made on clean sands. The downward flow through the filter compacts the sand, whereas upward flow in these tests tends, if anything, to prevent this compacting. In the studies now under way this point will be determined, as tests are to be run on each sand both with upward and downward direction of flow.

Slichter and King used upward flow in developing their methods, though in later work the former experimented with flow both downward and horizontal. For very find sands, as sand No. 6, only very low velocities can be obtained with upward flow, as the fine material is easily flushed upward to the surface.

The difficulty with the fineness modulus for our purpose is due probably to its giving undue emphasis to the larger particles, which is not done by the surface modulus. The studies of most experimenters agree in showing the importance of the finer materials in affecting flow through sand, though Slichter states that when the coarser particles are more than 30 per cent. of the total aggregate, they, rather than the fine material, determine the flow characteristics. This is contrary to Hazen's conclusions, nor does it agree with those arrived at by the speaker.

The point has often been raised as to whether the diameter taken as the effective size (10 per cent. of the material being finer than this diameter) really represents the mean diameter so far as it affects the flow of water through the sand. The present study may add a little information upon this point. If the head losses in a sand vary in some way in proportion to the surface area of the sand, as has been assumed in this discussion, one might define the mean diameter of sand grain, from this viewpoint, as such a diameter that the particles finer than this diameter have a surface area equal to that of the particles coarser than it. Such a sand grain we may term the surface median, and a determination of its value from these data indicates that it is the diameter, on an average, of that grain than which 31.1 per cent. is finer. Substituting this value for the various sands in Hazen's formula, we get the results tabulated in Table 3. Using the value of "C," which gives the closest results with the effective size (C = 675),

TABLE 3.

RELATIVE ACCURACY OF EFFECTIVE SIZE AS AGAINST SURFACE MEDIAN IN HAZEN'S FORMULA.

Sand No.	Effective size.	Diameter of surface median.	Per Cent. finer than.	Velocity (Hazen's formula).		
				Effective size.	Surface median.	Observed.
				c=675	c=325	
3	0.616	0.830	50.0	71.8	62.6	58.5
4	1.390	2.150	34.5	44.6	51.4	58.5
5	0.283	0.392	19.0	64.4	59.6	58.5
6	0.168	0.225	23 0	41.5	35.8	58.6
7	0.215	0.355	29.3	49.0	64.3	58.5
8	0.193	0.300	20.3	39.6	46.0	58.5
9	0.350	0.525	31.6	37.7	40.8	58.5
10	0.334	0.533	29.0	62.1	76.2	58.5
11	0.337	0.448	33.0	105.8	90.5	58.5
12	0.328	0.450	41.0	69.8	63.3	58.5
	Average error.....			16.15	12.55	...
	Average error in per cent.....			27.6	21.5	...

and comparing with the results obtained by using this surface median diameter instead of the effective size and with "C" as 325 (the value which gives closest results for these sands), we see that a closer approximation as to flow may be obtained by using the latter factor than by the Hazen factor. In other words, from the present data it would appear that results, using the smaller diameter (effective size), are more in error by 28.3 per cent. than those obtained when the larger size (approximately 31.1 per cent. finer than) is used. Hazen's formula is based on surface area, since V varies as the surface area πd^2 of the sand, where d is the diameter of the average size of grain so far as it affects the value of V.

The advantages claimed for the surface modulus method over Hazen's method are

1. A somewhat greater accuracy — in these tests 13.6 per cent.

2. A greater ease of application. There is none of the uncertainty as to the value to be used for a coefficient, where an error in judgment may result in very great variations as to results. It lends itself more readily to use by contractors furnishing materials, since they need but to substitute the results of the sieve analysis in the formula given, to get the surface modulus.

To compare the proposed formula with Hazen's, it may be written in a similar form, adding a term to correct for temperature and keeping in mind that the present data are for 72° F.

$$V = S^{-2.25}\, h\, f(t)\, 0.00742^{-1}$$

or $$V = 134.8\, S^{-2.25}\, h\, f(t)$$

where h = the $\frac{h}{l}$ term of the Hazen formula

and V = velocity in feet per minute.

These tests have been too limited in number and scope (covering only ten sands) to warrant the making of definite conclusions. Additional data derived from the tests which we now have in progress may modify the coefficient suggested in the formula, but the following tentative conclusions are given at this time, with the hope that they will call the attention of the profession to the possibilities of determining the flow characteristics of a sand by a study of its surface areas, and with the thought that the data given may be of use to other investigators.

Conclusions.

1. The surface modulus of a filter sand gives a fair approximation of transmission capacities and head losses under varying conditions of discharge.

2. The method gives more accurate results with the sands tested than the other methods now in use based upon the mechanical analyses of the materials.

3. A sand is defined more specifically by its surface modulus than by its effective size and uniformity coefficient.

4. The graphs and formulas given herein may be used in comparing sands but are not recommended for use in predicting absolute values for filters until further study indicates the coefficients to be used for service conditions.

The King Aspirator, as used by King and Slichter, gave flows in a series of ten sands, which varied from observed flows by an average of 7.19 per cent.[3] This indicates that the Aspirator is one of the most accurate methods of predicting flow through sands that has been devised as yet. One cannot compare the surface modulus method with the results obtained by these investigators, as the sieve analyses of their sands are not available and the effective size as used by them is a very different factor from that used by Hazen. They define this term as "such a number that if all grains were of that diameter the sand would have the same transmission capacity that it actually has."[6]

The speaker wishes to acknowledge his indebtedness to W. J. Mahoney for assistance in making these tests, and to T. E. Stanton, F. N. S. Thomson, and J. G. Beagan for preliminary tests and preparation of materials used.

Discussion.

Thorndike Saville.* Abrams' fineness modulus for filter sands was reported on in 1918.[7] In 1922 the writer assigned to Mr. M. A. Hill, a graduate student in the Engineering School at the University of North Carolina, the problem of developing a chart with a probability base, on which filter sand analyses would plot as a straight line. In prosecuting these studies Mr. Hill analyzed, or used analyses from, some 120 filter sands in actual use in various plants in this country. Sands from nearly all of the larger plants were represented in the analyses used. Mr. Hill also computed the fineness modulus of these sands, to see if this factor was at all comparable with the more usual characteristics, effective size and uniformity coefficient. The specifications of the Ohio State Board of Health for an acceptable filter sand were provisionally adopted, namely, that the effective size must be between 0.35 mm. and 0.45 mm., with preference for 0.37 mm., and that the uniformity coefficient should not exceed 1.6. It was found that some 40 filter sands meeting these specifications had fineness moduli between 2.3 and 2.5, with preference for 2.45. These studies of Mr. Hill were reported on in 1922 and 1923 in "Research in Progress," published by the University of North Carolina. They were also called to the attention of the Committee on Sand Analysis of the American Water Works Association. In the general form of chart provisionally adopted as a result of Mr. Hill's studies, the abscissae are spaced in accordance with a special skew probability curve. The final chart will have the rulings somewhat modified.

The work of Mr. Hill, resulting in the development of a skew probability chart for sand analyses and indicating some utility in the use of the

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term "fineness modulus," did not seem to warrant publication until further studies had been made. These studies have been carried on intermittently since, under the direction of the writer, and some 150 analyses of actual filter sands have been collected.

At the present time Mr. R. M. Trimble, Instructor in Civil Engineering at the Engineering School of the University of North Carolina, is carrying to completion the studies begun by Mr. Hill. These studies have not, up to the present, included any investigation of surface modulus, as proposed by Professor Tyler. In view of Professor Tyler's work, however, all of the 150 filter sand analyses which we have are being reworked to find their surface moduli. It is hoped to publish the results of the entire investigation of filter sand analyses and plotting within a few months. The results of a study of so many sands should provide interesting comments on the methods and tests reported on by Professor Tyler.

The article by Professor Tyler reports the results of studies on only 10 sands, and of these only one was a filter sand. It is felt that while Professor Tyler's methods and formulae are highly suggestive and offer possibilities of usefulness, nevertheless the amount of material used and the number of tests made are far too insignificant to warrant any definite conclusions being drawn. The formulae which he proposes are possibly of a correct general form, but it is certain that a large number of tests of actual filter sands will considerably modify their character. Professor Tyler himself clearly recognizes the preliminary nature of his studies, which it is to be hoped he will supplement by a large number of tests on widely varying sands used for filtration and other purposes. The present methods of filter sand analysis are not scientific and it is probable that investigations such as those being conducted by Professor Tyler at the Massachusetts Institute of Technology and by the writer and associates at the University of North Carolina will result in improved and, possibly, more sound technique.

Mr. Trimble and the writer have analyzed Professor Tyler's manuscript which he kindly furnished us. Our specific comments are as follows:

1. Professor Tyler in column 5 of Table 2 has not computed the fineness modulus as defined by Abrams, but has presented (except for sand 12) a factor (6 minus the fineness modulus). This we have called to his attention, and he has courteously acknowledged the discrepancy and will be able to correct this by means of a footnote or otherwise before his paper is printed in the JOURNAL.

2. Consequently, Fig. 2 does not show the relation between fineness modulus (F.M.) and loss of head (h). Manifestly, h varies inversely with F.M. and not directly as shown in Fig. 2, for F.M. is directly proportional to coarseness, which is in turn inversely proportional to h. On the other hand, surface modulus (S.M.) varies directly with h, and thus Fig. 3 is correct for the limited data plotted. The true Abrams F.M. for Professor Tyler's sands are plotted on Fig. 5, and as would be expected the curve

has an opposite slope from the curve in Fig. 2. The approximate equation of the curve in Fig. 5. is $V = 0.618\ h(F.M.)^{4.9}$ meters per day, and the average percentage error is greater than that obtained from the Tyler formulae using surface modulus.

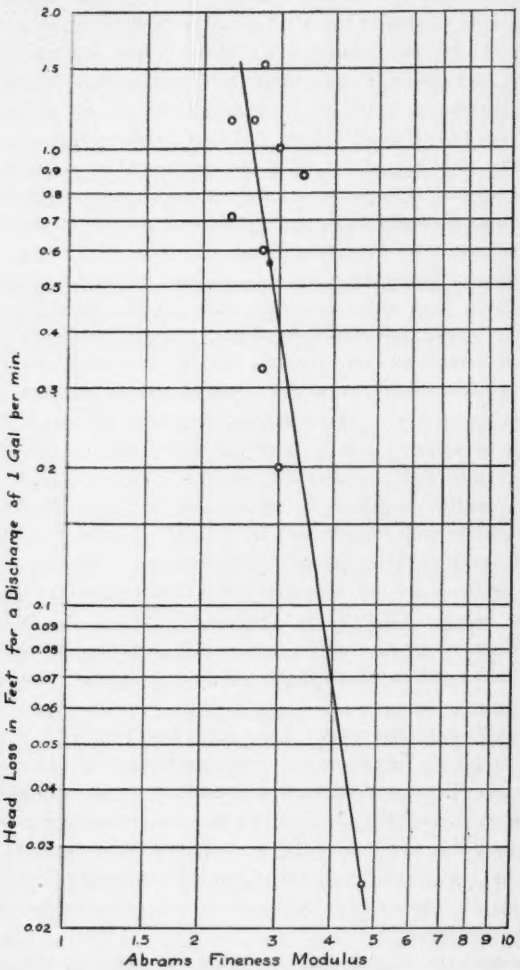

FIG. 5.

3. We are unable to check the values of velocity shown in column 8 of Table 2 by Professor Tyler's formula $V = 0.00742^{-1}\ S^{-2.25}\ h$, which must be multiplied by 439.2 to read meters per day. We do check the two formulae developed by him to fit his curve on Fig. 3. Our values of velocity,

calculated by the above formula, are shown in Table 4. It will be observed that our values differ more or less consistently from those shown in Table 2 by the following approximate relation:

$x = 2(58.5) - y$, where

x = Velocity calculated by us from Tyler formula

y = Velocity given by Tyler in column 8, Table 2.

TABLE 4.

Sand No.	Head Loss.	Velocity in meters per day from Tyler's formula.	Tyler's Column 8, Table 1.
3	0.20	41.3	82.0
4	0.025	57.9	58.5
5	0.87	110.6	31.0
6	1.55	60.7	56.2
7	1.16	52.0	63.9
8	1.16	55.7	59.7
9	0.33	34.8	95.0
10	0.60	59.1	55.9
11	1.00	108.0	31.6
12	0.71	44.2	74.9
Average error		16.95	14.23
Average % error		29.0	24.3

Moreover, our values show a slightly greater percentage error, which more nearly approaches the error obtained by using the Hazen formula. As a matter of fact, whether Professor Tyler's average error of 24.3% or our error of 29% be used, it is highly probable that as between these figures and the error of 32.6% from use of the Hazen formula, no conclusions should be drawn as to any superiority in accuracy of the Tyler formula over the Hazen formula. From such a very limited series of observations, with such widely varying observed errors, it is in our opinion quite improper to draw conclusions as to relative accuracy.

4. In Figs. 3 and 5, the lower part of the curve, upon which both the slope and form are largely governed, is fixed by a single observation. Consequently, it is entirely probable that a curve of a quite different form, and almost certainly with a different slope, will result when a larger number of observations are available. Either fineness modulus or surface modulus apparently has an advantage over the Hazen formula in that the variable constant C is eliminated. It remains to be shown whether either of these formulae are more satisactory or have a more scientific basis than the Hazen formula.

5. We have not experimented with the surface modulus, nor has time been available to analyze its mathematical foundations for this discussion of Professor Tyler's paper. The fineness modulus is a measure of the area under the mechanical analysis curve, and hence measures net volume of particles of material in a sample. On the other hand, surface modulus is

defined as a measure of the surface area of the particles of material in a sample.[8] There is no mathematical relation between the two except in a sand all the particles of which are nearly the same size. It seems reasonable to believe that surface area should be a function of head loss, varying directly with it. The surface modulus, however, is a measure of the surface area only if we assume similar distribution of relative sizes on successive sieve separations. Neither the fineness modulus nor surface modulus are exact representations respectively of the area under the mechanical analysis curve or of the surface area, when computed from the Abrams set of sieves. It is entirely conceivable that the fineness modulus and a surface modulus (the latter computed from a different series expansion) would very correctly indicate the water transmission capacity of a sand if a much larger number of sieves were used. The errors found from the plottings on Figs. 3 and 5 can possibly be explained from this fact. It should be remembered that both fineness modulus and surface modulus were devised in connection with the use of sands in concrete, and the exactitude necessary for evaluating accurately the water transmission capacity may not be necessary when considering concrete mixtures. It seems apparent to us that for either fineness modulus or surface modulus to be serviceable as true indicators of water transmissibility, a considerably greater number of sieves must be used. The work involved then approaches that necessary in computing the actual surface area, and it is not to be desired if some simpler and equally accurate method of analysis can be devised. We assume, with Professor Tyler, that surface area would be a true index of the water transmissibility, but experiments should be conducted to determine if this is a fact.

Professor Tyler has, at the end of his paper, started an incursion into the realms of probability methods of sand analysis, which we have been studying for some time. The surface median, as pointed out by him, has marked advantages over the effective size. It has the advantage over fineness modulus and surface modulus that it is changed relatively little in value where greater numbers of sieves are used. It has the disadvantage, as used by Professor Tyler in the Hazen type formula, of requiring a varying constant. Our studies of probability plotting of filter sands indicate that by the use of some value such as the surface median in conjunction with the standard variation, there may be better indicated the suitability of a sand for filtration purposes. We have not investigated as yet these factors as related to water transmissibility.

As Professor Tyler has in part indicated, the distribution of sizes of particles in a given sand is undoubtedly a measure of its water transmissibility, but the same factors which may indicate this attribute of a sand are not at all necessarily of equal value in indicating its suitability for use in filtration. Particularly in the rapid sand filter there is usually a marked stratification of the sand grains after a few washings, and the water transmissibility of the resulting mixture is likely to be quite different from that

of the sand when first put into the filter. This is not the case, at least to the same extent, with sands used in slow sand filters. It is very possible that one type of study should be made to determine the water transmissibility of a sand or soil, and quite another type of study made to determine the suitability of a sand for use in rapid sand filters. We regret that we had no knowledge of Professor Tyler's investigations until a few weeks ago. We hope in the future to correlate our work with that of Professor Tyler, and by mutual coöperation to eventually bring before the profession some improved methods of sand analysis for use in hydraulic and sanitary engineering investigations.

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SOME FEATURES OF FILTER DESIGN.

BY JAMES W. ARMSTRONG.*

[*Read September 10, 1925.*]

INTRODUCTORY.

In a general discussion of the filtration of water such as can be presented within the limits of a short paper, it is evidently not possible to say very much on any one phase of the subject. Many items that might appear pertinent have been omitted altogether, and the particular subjects discussed have been selected from personal experience rather than from fields that might appear to be of more interest to members of this Association, but about which I could speak with a less intimate knowledge. The most that can be hoped from a paper of this kind, is to stimulate the effort of those interested in the design or operation of filters to secure the best results with the materials with which they have to work.

THE WATER.

The designers of the earlier filter plants were handicapped by the lack of operating data, and in order to gain the much-needed information a number of experimental filters were built and operated. Plans that were worked out on the basis of these experiments began to be copied, sometimes without sufficient regard to the character of the water to be treated. As designers gained in experience, it became more and more apparent that each filter plant was a problem requiring special consideration. That waters as different as the silt-bearing Mississippi at New Orleans, the flashy Scioto at Columbus, with a total hardness varying from 90 to 480, and the clear but highly colored water at Providence should require different treatment was evident; but that streams like the Gunpowder and Patapsco, with watersheds adjoining and similar, should require different treatment was not so apparent. Some features of design that need special study with reference to the character of water are: grit chambers, mixing chambers, coagulating basins, size of sand grains and the application of chemicals.

THE WATERSHED.

It is not possible for every city to exercise control over the source of its water supply, but for such cities as receive their water from small streams, the purification process may be greatly simplified and cheapened by the proper supervision and control of the watershed. This is especially the case with streams flowing through hilly country over clay or easily eroded soils. If the shore line for a considerable distance from the water's edge

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can be kept in grass or planted in trees or shrubs to prevent erosion, the sudden increases in turbidity, so troublesome to filter-plant operators, may be greatly reduced.

If in addition an impounding reservoir of sufficient size can be created, the water delivered to the purification plant may have many of its characteristics changed for the good, as the experience with the Loch Raven Reservoir will indicate. The shore line of this reservoir, due to its very irregular shape, extends for about 50 miles and is absolutely controlled by the city. The following are some of the benefits resulting from the creation of this reservoir:

The first is a great reduction in the number of bacteria in the raw water, especially those of the colon variety. The 20° counts used to vary from several hundred to 800 000 per cubic centimeter, whereas now they never exceed 13 000 per cubic centimeter. The turbidity which used to vary from 10 to 5 000 was reduced to an average of about 15 and has never exceeded 200. As a result of this change, the city has saved thousands of dollars worth of chemicals each year since the dam was raised.

Another gain has been in the coolness of the water during the summer. The maximum temperature of the water reaching the plant is now about 65 Fahrenheit, which is 6° lower than the average of previous years.

There has also been a saving in the matter of cleaning the coagulating basins. Once a year now suffices, whereas in the past it was necessary to clean them two or three times a year.

From the above, it can be seen that even a partial control of the watershed may become a function of filter-plant design, on account of the many ways it may affect the character of water to be treated.

Mixing Basins.

The importance of properly mixing chemicals with the water in such a way as to secure the best floc with the least use of coagulant, has been more and more recognized of late. Yet there is probably no problem in connection with the filtration of water that has been the subject of more controversy, unless it be the subject of filter strainer systems. Many of the smaller plants have no mixing basins at all and seem to get fairly good results, but I believe at an excessive cost for chemicals.

Laboratory experiments indicate that, in order to secure the best results, the water should be violently agitated immediately on application of the coagulant; afterward, the agitation may be reduced and excellent results obtained; but if the process is reversed and the coagulant be applied to water that is moving very slowly and with little agitation and is afterwards agitated, no matter how violently, poor or very indifferent results follow.

Two factors enter into every problem regarding the coagulation of water: the first agitation, and the second the time element. It is evident that agitation is the more important factor, but as far as I know it is not

possible to assign definite values to each. Further experiment is needed to throw light on this subject. It is possible that mixing basins of the future will combine mechanical agitation with the baffled type of basin in general use today. In small plants, where it is difficult to secure funds for construction, mechanical agitation might be cheaply and satisfactorily used.

Perhaps the commonest type of mixing basin is that with around-the-end type of baffle. The advantage of such a type is that a natural hydraulic gradient is maintained throughout the plant for all possible rates of flow, with just sufficient loss of head to overcome the necessary frictional resistance of the channels. This means a minimum pumping lift at all times, and a proper carrying velocity can be maintained to secure the suspension of the floc. Should the velocity be too slow, sediment will be deposited until a carrying velocity is secured, and if the velocity is increased, scouring action will take place until the required area of channel has been reached.

Experiments made at Montebello under regular plant operation with mixing basins of this type having thirteen 180° turns, show that there is a distinct gain in the subsiding value of the water at each succeeding turn. For example, a sample of water taken at the first bend will require seven or eight hours to settle sufficiently for filtration, while a sample taken at the 13th bend will settle in less than two hours. The value of each turn, up to the fifth, seems to be nearly constant; later turns give slightly reduced values.

From the fact that as the rate of flow decreases, the total loss of head through the mixing basin also decreases, it is evident that the total head pumped against is always a minimum, a condition that does not hold with the over-and-under type of baffle. I understand excellent results have been secured at Sacramento by several circular mixing basins where the water flows from one to the other and is agitated in each by revolving paddles. The hydraulic jump, as advocated by Mr. Ellms, may give splendid results with many waters, but should be supplemented by additional mixing if the best results are to be secured.

Coagulating Basins.

The ideal coagulating basin is one in which the water enters in a thin sheet at the top of one end, moves uniformly and slowly across the basin and is withdrawn over a weir at the other end. Such a basin is sometimes found in a small plant, but construction features, and the difficulty of obtaining complete weir action at the outlet, make its occurrence very unusual. The advantage of such a basin lies in the fact that the movement of the water is uniform and at the surface, leaving the lower part of the basin as a quiet zone where the floc that has begun to settle can complete its journey to the bottom without disturbance.

In many plants structural reasons seem to make it necessary to admit and withdraw the water from the same side of the basin. In operation, the water passes from the inlet to the outlet around a single baffle, which di-

vides the basin approximately into halves. No matter how carefully openings for the entrance and withdrawal of water are spaced, it does not flow uniformly through the basin, but follows the line of least resistance. Surveys of mud deposits in the basins at Montebello show that the greatest deposits were against the baffle on the incoming side and against the outer wall on the outgoing side, and that the mud surface sloped away towards the corners where the flow was sluggish. This irregular mud surface shows very clearly that the subsiding values of different parts of such basins vary greatly.

In an endeavor to secure a more uniform flow and, consequently, a more uniform deposit of sediment throughout the basin, some submerged cross baffles were built in one of the basins. The design of the baffles was predicated upon two assumptions: If the flow of water could be confined to a thin sheet at the surface, the velocity across the basin would be more uniform, and as the water in the lower part of the basin would be undisturbed, there would be nothing to hinder the settlement of floc. It is a matter of common observation that when flowing water meets an obstruction such as a submerged baffle, there is a tendency to pick up sediment and carry it over the top. In order to prevent sediment from passing the baffle, it was capped with a top made in the shape of a parabola and extending 2 ft. in front.

It was reasoned from the well-known characteristic of a parabola to reflect light in parallel lines, that sediment in the rising current of water would, upon striking the parabola, be thrown downward and deposited instead of being carried over into the next compartment. In order to give a positive outward sweep to the water entering the basin and prevent returning under-currents, a wooden apron about two feet wide was built along the top of the entrance baffle. The building of this baffle added greatly to the value of the basin, as the mud was deposited much more uniformly than formerly, and immediately after passing the cross baffle there was a marked decrease in the depth of the mud. Cross baffles in coagulating basins would be most effective with waters carrying considerable sediment, but would be of doubtful value with waters of turbidities less than 25.

The matter of cleaning coagulating basins is of considerable importance. An otherwise desirable site for a filtration plant may have to be rejected if a satisfactory way of disposing of wash water and sludge from the basins cannot be found. In waters carrying such heavy sediment as the Mississippi at New Orleans, where grit reservoirs are necessary, it is very difficult to clean them by flushing, and means for mechanically removing the deposits should be provided. But in most plants, a flushing system is entirely satisfactory and basins as large as those at Baltimore, where they contain thousands of cubic yards of sludge, can be cleaned in 36 hours.

Convenient hose connections should be provided so that the men can work with a minimum length of fire hose. Hose streams are not sufficient in themselves as they do not supply an adequate volume of water for re-

moving the sludge. Larger pipe lines supplying raw water simply for carrying the sludge to the drains will greatly facilitate cleaning of the basins. With the proper flushing devices, a single gutter in the center of an ordinary reservoir will prove satisfactory, if the slope of the floors and gutter are enough to give a carrying velocity.

Pipe Galleries.

The most objectionable point of some filter plants is the pipe gallery. A crowding of pipes and valves into a narrow space makes the place very inaccessible and one consequently neglected by the employees. Local conditions sometimes make it very difficult to get a desirable pipe gallery. Even after the most careful consideration there will be probably some features that the designer would like to change but finds he cannot. In the new plant now under construction at Montebello, a happy combination of circumstances has resulted in pipe gallery as free from obstruction as any that I have yet seen. Concrete conduits and compartments have in most cases replaced special castings. The controllers are in a pit connecting two concrete compartments, one opening into the filters and the other into the filter effluent conduit.

Concrete.

In the earlier days of filter plant construction, reinforced concrete seemed to meet all structural needs of the designer, but after a few years of service it was noticed that certain sections of concrete, particularly in the colder climates, began to disintegrate. The reason for this has not always been easy to discover, and the remedy for the trouble, even when known, is still more difficult to apply. While the cause of the deterioration of concrete is not altogether known, it seems two very important factors enter into it, which have not been sufficiently considered, one the quality of the sand, and the other imperviousness.

Great attention has been paid to the strength of cement as tested with standard Ottawa sand, but little or no attention has been given to testing cement with local sand. The disintegration of concrete can sometimes be accounted for by the use of local sand containing impurities of an organic nature that are entirely overlooked. A slight seepage of water through concrete walls has often been regarded as of little significance, but recent careful observations seem to point to the fact that any concrete structure through which water is seeping is doomed and will ultimately fail altogether. This is particularly true in places subjected to frost action. Concrete to safely withstand water pressure must be impervious, and anything that can be done to secure this, whether it be in the way of better grading of materials, more care in mixing and placing, the addition of lime or other compounds to make the concrete flow into the forms more readily, or the application of any substance or liquid to the outside of the concrete to prevent moisture from penetrating, will help greatly to prolong its life.

There is a combined chemical and mechanical action continuously at war against water-bearing concrete. The calcium compounds are soluble in the presence of most waters. Even calcium carbonate is soluble in waters whose pH value is below the solubility equilibrium. Any water with pH value of less than 7.5 and alkalinity of less than 100, will dissolve calcium carbonate. In the presence of waters of low pH value such as are found in many places in New England, the calcium compounds in the concrete are gradually dissolved and the evidence of such action is indicated by white efflorescence or by deposits on the surface of the concrete. When concrete is submerged the same dissolving action takes place, but there is no visible evidence of it unless the surface begins to flake off. Not only is the calcium attacked but the aluminum compounds are slowly and gradually dissolved. The leaching out of these chemical compounds robs the concrete of its strength and makes it very susceptible to the disintegrating action of frost. The rapidity with which the destructive work is accomplished depends very largely on the porosity of the concrete.

When the Montebello Filter Plant was first built, all the concrete was apparently of very excellent quality, but after a few winters it was noticed that in some of the walls concrete began to chip off at the joints where frost action could exert pressure against two adjacent surfaces. Each succeeding winter the spalling-off of the concrete became greater, until at the present time some of the baffle walls near the water surface have become completely disintegrated, while others are apparently in good condition. We believe the trouble is due to one of two causes: either to impure sand, or to the fact that the injured walls were not as impervious as the others. The fact that concrete in certain structures subject to water pressure is showing signs of distress, should be a warning to designers not to adhere too closely to theoretical considerations. They should make liberal allowances to compensate for these troubles which, like the poor, are always with us.

Economy in Construction.

In many filter plants throughout the country the filters are built directly over the filtered water basins. This means that the plant in all probability cost more than it should have done, as the columns and roof of the basin have to be very much heavier in order to carry the weight of the filters. If conditions permit, the separation of filters and basins will result in economy of construction. When reservoirs are to be built in excavation or partly in excavation, it will be cheaper to slope the sides and pave them with concrete, than to build either reinforced or gravity walls. Wherever structures are to be entirely submerged in water and remain submerged, wood may be safely substituted for concrete. Filter bottoms, baffles, and conduits may be economically and satisfactorily made of wood. Mixing-basin baffles can be built of wood much cheaper than of concrete and, in addition to cheapness of construction, changes can be made at a

moderate cost, whereas if the baffles were built of concrete, it would be practically impossible to remedy any error without very great expense.

In studying the general arrangement of a plant, it is well to consider the possibility of placing the various structures so that two of them will have a common wall between them, or that a part of one structure can be used as part of another. By using concrete channels and compartments for controlling the movement of water, results can be secured that would be almost impossible, or very costly, if cast-iron pipes were used.

Some Principles of Design.

A fundamental principle of filter-plant design is to make it as easy as possible for an operator to do the thing you want him to do, and as hard as possible for him to do the thing that you do not want him to do.

Automatic devices in many cases are very desirable, as they can do what no man can do, but they should be so associated with plant operation as to require frequent watching.

Mechanical devices should be the simplest that can be designed to do the work. Crude devices are often very satisfactory.

Cut out all the machinery possible, as everything mechanical sooner or later needs repair, and the repairs increase as time goes on.

Access to all machinery, piping, valves, and wiring is a great virtue in the eyes of the mechanics responsible for the maintenance of a plant.

Chemicals should be mixed and controlled as near the point of application as possible and open troughs should replace chemical piping if possible.

Beauty often costs no more than ugliness, and in a group of buildings can often be secured by a proper arranging and massing of materials. The ultimate appearance of things should be in the mind of the designer from the inception of his work.

Economy of construction and ease in operation rest with a compactly built plant. Large savings can sometimes be made by making one wall do for two structures.

Potentiometer for Recording Hydrogen-Ion Concentration of Water.

Ever since the determination of hydrogen-ion concentration of water became a factor in laboratory work, the problem of securing an apparatus that would be of practical value to the filter operator, by enabling him to apply chemicals to the water more accurately, has been a matter of considerable interest. For a number of years the Leeds, Northrup Company of Philadelphia has been working in conjunction with Mr. Baylis at Montebello to perfect their potentiometer and make it a practical instrument for accurately recording the pH value of the water.

In the earlier experiments platinum electrodes were used, but the results were not very satisfactory or reliable. Later it was discovered that

tungsten electrodes gave much better results. With the improved electrodes the instrument has been perfected until now it will accurately record on a chart the pH value of the water. The instrument is in reality a very sensitive volt meter in which .06 of a volt represents one pH. This instrument is accurate within $^1/_{24}$ of a pH or .0025 of one volt. It has been used at Montebello for some time as a means of determining the amount of lime to be added to the water.

The instrument does not record accurately unless the electrodes are submerged near the instrument, but by means of a 110-volt current, red and white lights can be flashed, indicating the limits of control at any distant point, which will inform the controller attendants whether or not the lime is being applied at the desired rate. Since using this instrument, we have been able to apply the lime much more accurately than heretofore. For our particular water it does not seem to work as well for the application of alum. In waters of low alkalinity, or acid waters such as are frequently found in the New England states, it might be very desirable for the application of both lime and alum.

Filters.

The size of a filter plant has much to do with its design. There are certain difficulties inherent in large plants that are not encountered at all in smaller ones. These things should be held particularly in mind by the designer. In small plants it is generally possible to satisfactorily operate the filters by means of valves controlled by hand wheels, and in such instances, especially in communities where little money is available for construction purposes, it would be unwise and an unnecessary expense to use hydraulic valves and operating-tables when common hand-operated valves would do the work as well.

In the earlier large plants the wash-water gutters were discharged into a central gutter, but it was discovered later that this form of construction in reality gave two separate filters regulated by a single controller. In order to insure the proper and uniform hydraulic grading of the sand in a filter unit, there should be no division whatever in the sand area. In a small plant there is no need of a central gutter and, consequently, no trouble of this kind should be experienced. While large filter units are probably more economical per million gal. of capacity than small ones, large filter units should not be built in small plants, as when one unit is being washed or repaired the percentage of plant capacity out of service becomes too great.

Filter Bottoms.

During the last few years there has been considerable controversy regarding the best type of filter strainer system. Different types have had their advocates, but recently the perforated pipe system seems to have been the favorite. There is probably no type of strainer system in use

which, when properly designed, will not give satisfactory results. The question of merit seems to center largely on economy and permanence of construction. With the perforated pipe system, the rusting of the pipe and the enlargement of the holes must be counted upon. The writer recently had occasion to repair a small filter plant that used brass strainers screwed into iron pipe which were imbedded in the concrete, and found that a number of the strainers were loosened and out of place, due to rusting of the threads in the pipe manifold. The air system, which is not imbedded in the concrete, had to be entirely replaced.

It is believed that the slat-bottom filters, of which there have been some written accounts recently, are the most economical yet devised. I am thoroughly convinced that there is no value whatever in the so-called strainer system with restricted orifices or strainers for the water to pass through. The only value of a restriction is to insure a proper distribution of wash water through the channels or pipe manifold. As far as I am personally concerned, I have no doubt whatever as to the satisfactory operation of the slat-bottom filters and the economy of their construction.

Filter Sand.

It does not seem possible to write specifications for filter sand that will fix a proper size for satisfactorily filtering all water. For instance, a water high in turbidity or a water high in organic matter will require a rather coarse sand, say from .5 to .8 of a millimeter in diameter, whereas a filter handling comparatively clear water, free from organic matter, can satisfactorily use a very much finer sand. For mechanical filters it is believed that the term "Effective Size" is rather misleading, as after washing, filter sand becomes hydraulically graded. The fine sand remains on the top and the coarse sand settles on the bottom. Therefore, the effective size cannot be arbitrarily fixed as a certain per cent. of the whole, but is in reality the sand directly on the top. When the floc strikes the top sand layer, it is immediately broken and any particles passing the fine sand on top have little trouble in finding their way through the increasingly large spaces between the coarser sand grains below, until they reach the underdrains.

These considerations indicate that if an optimum size of filter sand can once be determined, it should be as nearly the same size from top to bottom as it is possible to secure. If the best results are to be obtained, each water should receive special study, and even then it may not be possible to select a size of filter sand that will be entirely satisfactory. There will in all probability be seasonal or yearly changes that will cause the operator to wish on occasion that he had some other size. A 2-ft. depth in sand should be enough for any filter, and if the right sand size is used, good results can be secured with a lesser depth. Of course, in any mechanical filter it is necessary to have a well-graded gravel layer, whose top layer should be a little coarser than the sand and about 2 inches thick, to act as a supporting medium of the sand and prevent any of it from reaching the underdrains.

Wash Water.

In most modern plants, wash water alone is relied upon for cleaning the filters. It is generally applied at the rate of about 2 ft. vertical rise, or about 15 gal. per minute. It is usually desirable to provide separate pumps for washing filters, as the draught on the high-pressure mains is too great for most places. In a small plant a pump can be installed for washing directly, but in large plants the volume of water and the power required for operating a large pump for only short intervals of time, makes such a pump undesirable.

It is commonly the practice to install wash-water tanks and fill the tanks by means of a smaller pump. Where wash-water tanks are used, they should be placed as near the center of the filters as possible. At the new plant now being constructed at Montebello, the tanks are placed directly over two of the filter units. The pumps take their suction directly from the water channel beneath, and discharge vertically upward into the tanks. A Venturi meter is placed on the outlet line feeding each gallery.

It is a very desirable thing to know the rate at which wash water is being applied, and for that reason the wash-water pump should not discharge directly into the outlet pipe from the wash-water tanks, unless at a point between the tank and the meter; as otherwise the meter would not record the total flow. An illuminating dial, large enough to be read from any part of the building, would be of considerable help to the operator in knowing whether or not wash water has been applied at the correct rate.

Chemical Handling.

In small plants it is probably best to handle chemicals in barrels or bags. The cost of special machinery for handling them would be unwarranted unless it were a simple elevator for lifting them to an upper room. In large plants the handling of barrels and bags becomes a nuisance, and it is practically impossible where large quantities are used. All large plants should be designed for use of chemicals in bulk to be received in carload lots. Probably the best and cheapest way of lifting chemicals is by means of a bucket elevator, but this necessitates overhead storage bins. For the most economical operation of the plant, there should be no manual labor in connection with chemical handling. They should be lifted but once, that is, when they are first received at the plant, and from that time until the chemicals are applied to the water, all handling should be done mechanically, whether the chemicals are applied in the dry state or as a solution.

Chemical Feed Devices.

Among the many chemical feed regulators that are in use, probably none is free from trouble. In the plants that use solutions, the corroding and choking of piping and orifices are sources of endless trouble. Dry feed

devices also have their peculiar problems. Those who advocate the use of dry feed devices claim that their installation is much cheaper than devices that apply solutions, but the chemicals, in order to be properly controlled, must be pulverized or hydrated.

Accuracy of control seems to be, with the solutions, a factor especially desirable in large plants where slight variations from the desired amount might result in the loss of large sums of money. Many plants could profitably manufacture their own alum, and in those where this is being done the results seem to be giving satisfaction. Most medium or large-size plants have an adequate organization for making alum without additional help, and the following items of expense which must be charged against the product put out by any firm that sells alum, can be neglected in a municipally operated plant. These items are: overhead, labor, profit, the additional weight of chemicals due to the water of crystallization, and the additional freight and weight to be handled. It may sound strange to include labor as an item in favor of a municipally operated plant, but in a well-designed alum plant it will require no more labor to manufacture alum than it will to mix and control chemical solutions.

Turbidimeter for Reading Low Turbidities.

One of the features of filter-plant control, that has in the past been very unsatisfactory, is the matter of determining the turbidity of filtered water. It is practically impossible with the old type of turbidimeter to tell, with any reasonable degree of accuracy, the turbidity of the filtered water. In many plants turbidities are reported as zero, when in all probability they are as high as one or more.

In connection with studies made at Montebello, Mr. Baylis has finally evolved a type of turbidimeter by which turbidities can be read accurately to within one-tenth of one part per million. (See Fig. 1.)

Two glass tubes, about one inch in diameter and 30 inches long, are placed in the front end of a galvanized iron case with their bottoms about 2 in. above the floor of the case. In the back of this case, about 30 in. from the tube, is a 200-watt lamp, of which the full intensity of light is reflected upon the tubes. The light is admitted to the compartment under the tubes by passing through a sheet of cobalt blue glass. If distilled water is placed in one tube, and water with the slightest bit of turbidity is placed in another tube, it can be instantly detected by the intensity of the blue as seen by looking through the tube. The distilled water always shows the deepest blue. To use this device, standards have to be prepared for comparison, but improvements can be made which will obviate the necessity of using standards. A single tube can be used for holding the sample to be tested and comparison can be made by matching the shade of blue, as seen through the tube, with the different shades of blue glass.

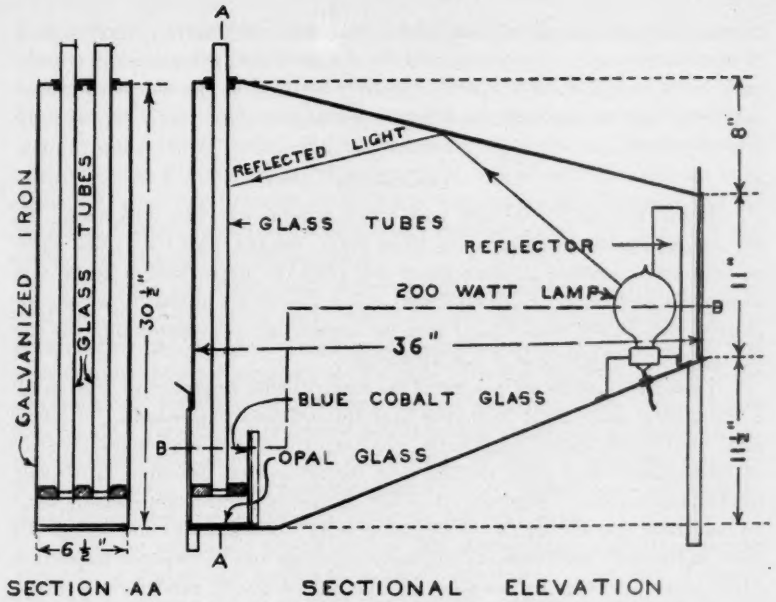

FIG. 1. — TURBIDIMETER.

SIGHT GLASS FOR DETERMINING THE CLARITY OF FILTER EFFLUENT.

Two essentials of every filter plant are: first, that the plant give enough water to supply the needs of the city; and, second, that the quality of the water should be the best possible. A recording rate of flow gage will indicate the amount going to the city, but the matter of the quality of the water is not easily determined. Loss of head has been tacitly assumed to be indicative of the quality of water, as it has been the means of determining the time when a filter requires washing.

There are certain times in the operation of a filter plant when loss of head may be a satisfactory means of determining the time for washing, but there are times when it may be a very unsatisfactory means. Under certain conditions filters need washing with a head as low as three or four, whereas at other times they may run a loss of head of over eight feet and produce a clear effluent.

At Montebello loss of head has been abandoned as a means of determining the time for washing filters and, as a substitute, a device has been in use for several years for determining the quality of the effluent. A 3 000 liter flask is placed in a box with a small circular opening in the front for permitting the observer to see the water which is being syphoned through the flask by means of $\frac{1}{8}$ in. copper tubing. A partition with a small circular hole in it separates the flask from a 200-watt lamp, of which rays, upon passing through the hole and the water, act very much like a sunbeam

passing through a small opening into an otherwise dark room. Every speck of suspended matter is revealed, and the shape of the flask tends to magnify each particle. The filter operator is thus enabled to detect the slightest turbidity passing through the filters — a thing we have not been able to do heretofore.

Discussion.

Paul Hansen.* We are very much indebted to Mr. Armstrong for his commentaries on mechanical filter plant designs, and I am sure all of us who are interested in the subject will read the paper with a great deal of interest and care. I am especially interested in his almost pipeless pipe gallery, but do not understand why he looped the wash-water pipe, as the saving over a single pipe is not apparent.

I was also interested in some of his remarks with reference to filter sand. I think he is quite right in saying that the ordinary expressions "effective size" and "uniformity coefficient" do not express the real characteristics of filter sand. But they are the best for all-around use that have been developed to date. However, it is not necessary even in purchasing sand to use these specific terms. One can specify, for example, how many per cent. of the sand shall pass certain sieve openings and be retained by certain other sieve openings. Knowles did that in specifying sand for the Pittsburgh filters. Taking it by and large, these terms are very helpful in purchasing sand, but where one wishes to indicate the condition of sand, that is, the stratification of a sand in a mechanical filter, some other forms of expression are perhaps more desirable. For determining the suitability of a filter sand for use in mechanical filters, other methods of diagramming sieve analysis are preferable to those in current use, which latter are intended primarily for showing the effective size and uniformity coefficient. Other methods of diagramming have been used at St. Louis and Baltimore.

Mr. Armstrong certainly put his finger on a very serious difficulty in the construction of filter plants when he pointed out precautions necessary to prevent disintegration of concrete. I do not think we can have it too strongly impressed upon our minds that mere seepages are dangerous. As Mr. Armstrong said, it has been the practice heretofore to regard seepages as unimportant, and we have always felt that they would take care of themselves. Whenever concrete is not dense enough to prevent the moisture from coming through, even though it does not come through in the form of a definite leakage, it is certain to disintegrate in climates subject to freezing weather.

John F. Laboon.† Mr. Armstrong made some mention of economy in design of filter plants, to the extent that a common wall should be used wherever possible. It strikes me this is a rather dangerous thing in some respects, inasmuch as a common wall between contaminated water and filtered water is more or less of a serious matter. In fact, it is so serious

*Of Pearse, Greeley & Hansen, Consulting Engineers, Chicago, Ill.
†Of J. N. Chester Engineers, Pittsburgh, Pa.

with a number of the State Departments of Health that they have legislated against it in their approval of plans for filter plants. I have one state in mind particularly that will not approve a common wall between a settling basin and a filter. We have always practiced the common wall design in shaping our settling basins, and, furthermore, we shape and dimension our basins in such a way that the least length of wall is obtained, but we have departed from the practice of building common walls between settling basins and filters, due to the danger of contamination. In fact, it is not permitted, as I said, in some states.

Regarding the sloping side reservoir: It is admitted that there is some considerable economy in some cases, under some circumstances, in the construction of sloping side reservoirs compared with, say, self-supporting gravity or reinforced concrete wall types. On the other hand, you have the additional feature of higher maintenance with the former type. There is presented a greater problem of construction, inasmuch as the embankments must be made practically non-settling in order to keep the concrete from cracking. You also have the factors of extra roof cost, and, due to the sloping sides, the reduced capacity of area, and so on.

Now, on the sand, I take it that Mr. Armstrong's statement would argue for a uniformity coefficient approaching unity. And that, I think, is being recommended in a great many cases. However, as regards the size of sand, as expressed by the term "effective size," I see a great deal of logic in that expression, inasmuch as the definition of your term "effective size" would practically make the top 10 per cent. of the sand really the size that you are going to specify, and the uniformity coefficient takes care of the underlying strata.

As to concrete, I think the subject of concrete is being appreciated more and more by the designing water-works men, due to what Mr. Armstrong has pointed out as being a very serious situation.

In regard to the organic matter in the sand used in concrete, this matter can be easily taken care of in the field by means of an organic test for sand. But I think the problem lies heavily in construction methods. It is very often the case that you find materials are nearly perfect but the workmanship slighted, and consequently you get porous concrete and segregated concrete; you get more leakage, in my opinion, through imperfect construction joints than because of segregation and the poor quality of the concrete materials.

What I want to point out is that even though the designer may take care of the design, construction, and operating features, the character of workmanship such a design receives in the field is a far more difficult problem to govern.

EDWARD G. BRADBURY.* I have observed that in a great many cases, perhaps most cases, this disintegration of the concrete takes place in spots, in different parts of the plant. It takes place in one section of concrete

*County Sanitary Engineer, Columbus, Ohio.

immediately adjacent to another portion which does not disintegrate, in which it is known that the materials were identical. It has been my experience of recent years that most of the contractors have been so thoroughly taught the methods of placing concrete that there is comparatively little lack of proper tamping or spading. But I have been impressed with the fact that concrete which is mixed a little too wet — not so much as to be drowned — will be porous and absorb water like a blotter. Last year I replaced one pier of a concrete trestle which was built with identically the same materials as all the rest of the structure, but which the records show had one batch placed too wet. That one batch could be located exactly, and that was the place where water was absorbed and disintegration took place, due to freezing several months after construction. I am convinced that a good part of the porosity and disintegration of concrete is due to a slight excess of water in the mixing.

MORRIS KNOWLES.* This paper of Mr. Armstrong's presents many admirable features, and perhaps not the least is that it shows that the water-works engineer must be a very versatile man. The author has touched upon many points. One is that of being a forestry engineer, versed in tree growth, to so protect his watersheds that the difficulties will be reduced to a minimum. The engineer must also be a good building designer, to produce the several attractive superstructures, because the plant shown us contains many pleasant features. He also must be a good bridge engineer, because there are some admirable bridges we saw in those pictures. After all, he must understand the materials with which he works, to secure safe and dependable results. We will refer to one of these features.

Much has been said on the subject of concrete, and one hesitates to say more, but all those who deal with the subject of construction in any form know that it is one of the indeterminate things, and one about which we are forever learning. Some experience in the Pittsburgh district, with which I presume undoubtedly Mr. Laboon is familiar, indicates that after all it is not always easy to determine just why the aggregate, whether gravel or sand, does not sometimes work well, or just how to make it work well. There are some very unexplainable examples of disintegration of concrete, — even concrete that has not been exposed to water or to severe frost action.

One of the theories advanced, about which we know but very little, but about which we have done considerable thinking, is that some of the gravel and sand, obtained from the rivers in the vicinity, has a coating of a colloidal nature, which is of a sewage character. Our rivers are becoming heavily laden with sewage, and it is quite within the realms of possibility, and some of us think it is quite likely, that this sand, which is dredged from the rivers, has a sewage film upon it, this to an extent which renders the material quite difficult to use in concrete with ordinary washings, and perhaps with any amount of washing that can be given it. That trouble would not be attendant with clean bank sand.

*Consulting Engineer, Pittsburgh, Pa.

Then of course we all know that it is not common sense, if one finds poor aggregate, to simply dump in a lot more cement, because that does not necessarily make the concrete any better; it does not in fact abate the evil or make the thing any sounder or stronger. The right thing to do is along the lines which are being studied at the present time, and which have been followed in the building of a very large stadium at Pittsburgh, in which the right mixture is closely adhered to by careful methods so that not so much is left to the discretion of the men upon the job.

The point to which Mr. Laboon refers, the speaker would be glad to say something about, because it appears that, unless we interpret the picture wrongly, there is a difficulty of having party walls between two kinds of water — that is, a polluted water and a purified water. This has been carried to the *n*th degree, in what Mr. Hansen calls the pipeless pipe gallery, in that the lower portion of the box or conduit is being used for clean water and the upper portion of the box being used to carry the settled water to the filters. You thus have a horizontal partition in this concrete box, and the horizontal partition is the only barrier between the polluted water and the pure water. The experience which some of us have had with some departments of health would preclude in some states the use of such construction, because of the fear the porosity of the wall would allow of the two waters being mixed. All of us should be careful, when we try for economy of construction, not to introduce such a thing. I am surprised a state department of health should allow it.

MR. ARMSTRONG. Don't you think that the danger has been exaggerated, that of mingling two waters separated by a concrete wall? With a raw water averaging less than 1 000, and coagulated water averaging less than 200 bacteria per cubic centimeter, the danger from contamination by seepage through concrete walls is rather remote, and the amount of pollution — if it can properly be called such — that could pass from a coagulated water into a filtered water would be infinitesimal, expecially when there are few *B. coli* in the water.

MR. KNOWLES. Of course germs are the things which cause disease. May I say that with the kind of concrete which you showed us in one of those pictures if it occurs on the horizontal barrier it would be fatal to any complete separation of the water.

MR. ARMSTRONG. I do not think we have such a condition there. I think that point is overstressed.

GEORGE A. SAMPSON.* In selecting a filter sand it should be recognized that the effective size does not remain the same after use as when the sand is placed in the filter. A considerable portion of the finest particle is wasted in washing the filter, especially where a high velocity wash is used, and oftentimes it is advisable to scrape off an inch or more of the top surface when the filter is placed in use or subsequently. I have in mind one case where the effective size of the filter sand was 0.30 mm. and two years

*Of Weston & Sampson, Consulting Engineers, Boston, Mass.

afterward an analysis showed the effective size to be 0.40 mm. Although this increase is likely beyond the ordinary, it is probable that an increase of 0.05 mm. is not uncommon.

MR. BRADBURY. It might be added to that statement that in cases where a softening process is used, the size of the sand grain, as is well known, is materially increased by a coating of lime or soda.

MR. ARMSTRONG (*by letter*). In reference to Mr. Hansen's query regarding the wash-water pipe loop: there are several reasons for adopting it. A single line would have required 30-in. pipe whereas the loop was of 24-in. pipe. The 24-in. loop gave better hydraulic conditions and was actually several thousand dollars cheaper. The total weight of the loop was greater, but the weight of specials was greater in the single line, and the price of special work was so very much higher than the price of straight pipe that the little added weight was more than compensated for by the saving in cost of specials.

If a single line had been used, it would have occupied the only available head room in the gallery, and there would have been no free space to walk in.

Regarding the terms used in describing filter sand, referred to by Messrs. Hansen and Laboon, when sand was first placed in Montebello filters an analysis was made for each half of each filter, and the results were plotted on paper ordinarily used for the purpose. An attempt to compare the 64 different charts proved too much of a task, and they were re-plotted very much as test borings are. By starting the plottings from a given line at the top and working downward, a diagram of the sievings can be made that will make it easy to compare the sand in the various filter units.

It was not my intention to discuss sanitary matters in this paper, but Messrs. Laboon and Knowles have raised such a point in questioning the propriety of using concrete walls as a means of separating water in its different stages of treatment, particularly in separating filtered water from treated water. It is a good talking point and leaves the impression that one so particular would stop at nothing to safeguard the public health.

In looking at the matter carefully, in the light of both construction and operating experience, I can see nothing to justify an engineer in expending large sums of money in building two walls when one would do, simply to comply with the ideas of some board of health the members of which may have had no filter experience. There are boards of health that take a broader view and there are engineers who are willing to risk criticism and build things the way they believe to be right.

In most filter plants coagulated water is not grossly polluted, and if some unfiltered water should seep through concrete, it does not mean that the filtered water has been contaminated. There is no evidence that water seeping through concrete is any worse than the same kind of water passing through filter sand; in fact, there are two reasons for believing that it may be better. Water passes through filter sand at a very high rate, but it seeps through concrete very slowly. Water passing through concrete is

highly alkaline and caustic, and bacteria have difficulty in surviving in such water.

A positive leak of any size could hardly occur in any well-built plant, but it would have to be a very bad leak indeed that would admit as much objectionable water into the filter effluent in a month as would enter in a single day from what might be called the back-wash from washing filters.

The "pipeless pipe gallery" which Mr. Knowles refers to as carrying to the *n*th degree the use of party walls for separating two kinds of water, happens to be above reproach according to his own standard, as no raw water or treated water enters it. The treated water enters the filters from the opposite side and the drain is beneath and does not carry water under pressure.

PROCEEDINGS.

The following is a synopsis of such parts of the proceedings at the Convention as appears to be of value for the record.

FORTY-FOURTH ANNUAL CONVENTION.

Held on board

The S.S. *Richelieu*

en route Montreal to Quebec, Saguenay River, etc.,

September 8, 9, 10 and 11, 1925.

A special train transporting the Convention party left Boston on Sunday evening, September 6, 1925, for Thousand Islands, arriving at Clayton, N. Y., the following morning. Transfer was made to the Hotel Crossmon at Alexandria Bay, where the party remained during the day.

On Tuesday morning, September 8, a steamer was taken for Montreal where the party was transferred to the S.S. *Richelieu*, upon which the technical sessions of the Convention were held.

Tuesday evening, September 8, 1925.

The Convention was called to order by the President, Stephen H. Taylor. In opening the Convention President Taylor spoke as follows:

Ladies and gentlemen: We are very glad to see so many here. I was a little afraid that because we got you up so early this morning, perhaps you would all have retired before now. I am sorry that the program is delayed a little on account of the lateness of the dinner, but here we are, and we are going to make the preliminaries very short, and then let those who want to, dance, and those who feel the effects of early rising and do not want to dance, can retire early if they wish.

It has been the custom in opening our conventions in the various cities to be welcomed by the high officials of the city in which we happen to be meeting. I believe our program also carried the statement — someone called my attention to the fact tonight — that some high officials of the Government would be here and address us at dinner time. However, the only Government officials I have seen so far have been the customs officers, and they did not have very much to say.

We have with us tonight, instead of the Mayor or any high officials of the Canadian Government, a Mayor from what we like to say is the very best city on earth, — New Bedford, — and it gives me great pleasure to introduce the Honorable Edward R. Hathaway, Mayor of New Bedford. (*Applause.*)

Remarks by Honorable Edward R. Hathaway.

Mr. President, ladies and gentlemen of the Convention: I want to assure you that I am very happy indeed to come here on this very delightful occasion. I wondered, as the President introduced me, about the feasibility or the wisdom of an introduction, because I have been in your company now for about three days and I feel somewhat at home with this splendid gathering of men and women.

We are embarked tonight, I understand, on this boat for a four days' trip. I hope that each and every one of us will dismiss the formality of an introduction; that we will make ourselves at home and enjoy ourselves, as I am sure we can by meeting each other and participating in any discussion that arises.

I know that this gathering is going to discuss the many problems pertaining to water and water systems. I am not an expert in that particular line myself. I shall perhaps not enter into the discussion, but I feel that this Convention is going to be materially beneficial to every city and town in New England. I feel that after our deliberations and our discussions here that when we disembark next Saturday for our respective places of abode we will all be enlightened; we will all feel as if we had had a vacation — a splendid trip, and a trip that has resulted very materially to the benefit of the cities and towns that are represented here.

I want to thank you all most heartily for asking me to say a word or two — I did not come here to deliver an address. I wanted to come here because this organization of men has honored the city of New Bedford that I represent by the election to the high office of president of this organization a man whom we all in New Bedford love and respect, — Stephen H. Taylor. (*Applause.*) I rarely go to conventions, but when he said to me, "I wish you would come, Mr. Mayor," I felt that if this organization esteems him as we do in New Bedford, as indicated by the high confidence that you have placed in him by electing him as your president, when he invited me to come here I felt that I ought to respond to his invitation and participate with him in the instructive and pleasant time that we are to have here. So I came, and I am not sorry that I came. Thus far I have had a very delightful trip, and I know I am going to continue, and as time goes on and as we become better acquainted I know that we will have a better time.

I want to simply reiterate again that I am happy to be here; I am glad that you have respected a man like Mr. Taylor by honoring him in electing him to the position that he holds. We in New Bedford are equally as fond of him as you are. I trust that when we all, as I said before, depart for our homes, we will have the remembrance of a very splendid trip.

I thank you. (*Applause.*)

President's Address.

President Taylor. The next on the program, ladies and gentlemen, is the president's address; and realizing that we are perhaps not in a mood

for a very lengthy address, I am going to make it very short — as someone has said, when asked about the proper length of a lady's skirt — just long enough to cover the subject but short enough to be interesting.

The winter meetings were well attended and enjoyed by all. The records show the average attendance for the past year to be the largest of any; also that each meeting had a larger attendance than the previous one. This record is very pleasing and encouraging to your officers. Keep it up.

On account of alterations at the City Club, where those meetings were held, it became necessary to guarantee them a larger revenue than formerly or seek a new meeting-place. The new Chamber of Commerce headquarters was seriously considered, but it was finally decided to use the larger room at the City Club. The attendance has been sufficient to take care of the guaranteed revenue required, and the meetings were made more pleasant on account of the improved facilities and the presence of the organ which, under the skillful handling of Mr. Louis Fall, added greatly to the enjoyment of the lunches.

Thanks to the energetic work of Mr. Frank A. Barbour, who constituted the program committee, some very excellent papers on interesting subjects were presented. These have kept the JOURNAL up to a high standard.

It is most essential to the Association that the papers, and through them the JOURNAL, be kept to this high standard of quality and interest. While we have a membership of something over 800, our average attendance at the winter meetings the past year was about 150.

This means that a great majority of our members depend on the JOURNAL for the value they receive from membership in the Association.

Those of us who are privileged to attend the meetings greatly enjoy the personal contact with men in the same line of work and the exchange of personal experiences. Unquestionably, the benefits derived by the town, city, or water company which we represent, on account of our attendance at these meetings, are sufficient to warrant the payment of the expenses of such attendance. It is my belief that if the proposition were properly presented to these corporations, arrangements would be made for the payment of such expenses. This would result in mutual advantage to the Association and the corporations we represent.

Our Association was one of the earliest and is one of the best agencies for the interchange of experiences and ideas along the lines of developing and improving public water supplies, which mean so much for the benefit of every community. It is interesting to note the great improvements which have been made in the water supplies of the various communities of the country, not only as to quality and quantity, but also as to administrative methods, since our organization has been in existence. The New England Water Works Association has done its share in bringing about these improvements. No other commodity is as necessary to the life of a community as ours, and it behooves us to take advantage of every oppor-

tunity of keeping the plant in which we are interested up to the highest standard of quality and efficiency. This Association offers one of the best mediums to that end and will continue to do so as long as each of us do our part by the presentation of papers and entering into the discussions on topics of interest in our work.

In response to an invitation from Mayor Quinn and the Cambridge Water Board, the Association was privileged to make a visit to the new filter plant in that city. This visit was very instructive and enjoyable, and the thanks of the Association have been extended to our hosts for their very fine hospitality on that occasion.

The June outing at Providence, held in conjunction with the Boston Society of Civil Engineers, proved to be a June wetting. In spite of the weather, it was well attended and was an enjoyable and instructive event, affording an excellent opportunity of seeing the progress on the new water supply works since our meeting there three years ago. The committee in charge of the outing deserve credit for the excellent arrangements which they made and carried through. While the weather made necessary some sudden changes in the program, the committee was equal to the occasion and met all the handicaps nobly.

Your officers have held frequent meetings and taken care of the routine and special work of the Association, and its joint work with other associations of a similar character.

A spirit of coöperation has prevailed throughout the year which has been very pleasing to your officers, and I now wish to express my thanks to all officers and members for their demonstration of this spirit.

No call has been made which was not heartily responded to. It is this spirit which keeps our Association in the front rank and I sincerely hope to see it continue for many years to come. As long as it does we may be sure of keeping our place as one of the leading technical organizations of the country.

After this Convention I join the ranks of the has-beens, and I now wish to express my thanks for the honor which you have conferred on me by allowing me this very happy year as your President. I shall always be glad to serve the Association in any way possible.

I neglected to announce that we also have with us another mayor, who is rather modest and does not care to be formally introduced, but I am pleased to state that the Honorable Peter N. Gagne, Mayor of Somersworth, N. H., is with us, an elected official, and I hope that he will enjoy the trip with us. (*Applause.*)

Award of Dexter Brackett Memorial Medal.

PRESIDENT TAYLOR. The next business on the program is the award of the Dexter Brackett Memorial Medal, and I will ask the Secretary to report on that subject.

SECRETARY GIFFORD, *(reading)*:

"Boston, Mass., July 22, 1925.

Executive Committee,
New England Water Works Association,
Boston, Mass.
Gentlemen:

The Committee on Award of The Dexter Brackett Memorial Medal for the year 1924, appointed at the meeting of the Executive Committee March 10, 1925, submits the following report:

We have examined the papers published in the JOURNAL for the calendar year 1924, and acting under the conditions imposed by the rules governing such award, we recommend that The Dexter Brackett Memorial Medal be awarded to Robert E. Horton for the paper entitled 'Determining the Mean Precipitation on a Drainage Basin,' published in the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, March, 1924.

Respectfully submitted,
FRANK A. MARSTON,
THOMAS A. WIGGIN
A. R. HATHAWAY."

PRESIDENT TAYLOR. Unfortunately, Mr. Horton is not here to receive this medal personally, but the medal is here and anyone who has not already seen one, and wishes to, will have the opportunity to examine it. It will be here on the desk.

I will ask Mr. Charles W. Sherman to explain, perhaps, to some of the people who do not realize, just what the Dexter Brackett medal is. It was to be his duty to present it, but he can do so by proxy.

CHARLES W. SHERMAN. Mr. President: It is always a pleasure to say a few words about Dexter Brackett and his work for this Association. Some of the younger members probably remember him only by name, but for many years he was a foremost figure in this Association, and even after he ceased to attend its meetings regularly he exercised a very powerful influence over its programs and its doings, — not so much directly as by suggestion.

Mr. Brackett was probably as responsible as any single individual for the high quality of the programs and papers which this Association was able to present for a good many years when comparatively little was being done in that field, and the fact that such was the case enabled this Association to grow — not only keep alive but increase its membership from about 200 in the early days to nearly the size we have now.

Mr. Brackett, as some of you perhaps do not know, started his career as assistant in the City Engineer's office of Boston, and was soon transferred to work for the Water Works of Boston; some years later he became superintendent of the old "Eastern Division" of the Water Works, which was the distribution system of the Boston Water Works, and administered it for a number of years, after which he went back to the engineer's office until the formation of the Metropolitan Water Works, when he became engineer of the distribution division of that system, and so continued until the re-

tirement of Frederic P. Stearns, when he succeeded him as chief engineer.

I had the good fortune to serve under Mr. Brackett in the Metropolitan Water Works, and partly for that reason, I presume, was one of the Committee appointed to formulate the Dexter Brackett memorial after Mr. Brackett's death. A number of the members of this Association, realizing how much he had done for it, believed that the best way to perpetuate his memory in the Association was to establish a prize which should bear his name and which should be annually awarded. The Committee appointed by the President for that purpose solicited subscriptions and had a medal designed and prepared and turned over to the Association.

The memorial was formally established and accepted by the Association in 1915, and the first award was made in 1916, so that it is not an old prize. This is the ninth award, I believe. But this particular award this year to Mr. Horton marks a very unusual occurrence, inasmuch as it is a second award of the medal to the same individual. Mr. Horton received the medal in 1919 for a paper on the "Measurement of Rainfall and Snow"; he now receives it the second time for a paper on "Determining the Mean Precipitation on a Drainage Basin." The papers are on similar subjects, as you will note, and those of you who know Mr. Horton will realize that he is one of the great authorities of the world on this matter of rainfall and run-off on drainage areas.

The terms of the award are that it shall be given for the most meritorious paper published during the year by a member of the Association. There were several very good papers presented to the Association last year, some of which did not come from members and which therefore were not eligible to the award. Perhaps it may be justified, for one who was not a member of the Committee on the award, to guess that if they could have reasonably found an excuse they would have given it to one of the other papers rather than to award it a second time to the same man. I do not know that that is a fact; I am merely guessing. But the fact that they were not able to do so anyway speaks additionally well for Mr. Horton's paper. (*Applause.*)

In accordance with the provisions of the constitution of the Association, the President announced that if there were no further ballots to be filed the polls would be closed, and there being no response the polls were declared to be closed. The President later announced the appointment of Roger W. Estey, Harry W. Dotten, and Arthur G. King as a committee to sort and count the ballots.

WEDNESDAY, SEPTEMBER 9, 1925.

Morning Session.

Paul Hansen, Consulting Engineer, Chicago, Ill., read a paper entitled "Tastes in the Water Supply of Marquette, Mich., due to Phenol Wastes." The paper was illustrated by lantern slides. George A. Sampson and Morris Knowles participated in the discussion.

A paper prepared by Harry W. Clark, Director and Chief Chemist, Massachusetts Department of Public Health, on "The Question of Iodine and Water Supplies," was read, in the absence of Mr. Clark, by the Secretary. Arthur D. Weston discussed the paper.

A paper by Frederick E. Field, Filtration Engineer, Montreal Water Board, Montreal, P.Q., on "The Filtration Works of the City of Montreal," was read, in the absence of Mr. Field, by the Secretary.

Evening Session.

A paper on "The Lawrence Water Supply, Investigation and Construction," prepared by Morris Knowles and Myron G. Mansfield, Consulting Engineers, Pittsburgh, Pa., and Patrick Nugent, Superintendent of Water Works, Lawrence, Mass., illustrated by lantern slides, was read by Mr. Knowles. J. F. Laboon, Paul Hansen, Patrick Nugent, Edward G. Bradbury, and W. P. Mosteller participated in the discussion.

James W. Armstrong, Filtration Engineer, Water Department, Baltimore, Md., read a paper on "Some Features of Filter Design," illustrated by lantern slides. Paul Hansen, J. F. Laboon, E. G. Bradbury, Morris Knowles, and G. A. Sampson took part in the discussion.

THURSDAY, SEPTEMBER 10, 1925.

Morning Session.

A paper prepared by E. Sherman Chase of Boston, Mass., on "A Score System for Grading Water Supplies According to Sanitary Conditions," was read, in the absence of Mr. Chase, by Charles W. Sherman. The discussion was participated in by Charles W. Sherman, Beekman C. Little, J. Frederick Jackson, Arthur D. Weston, and M. N. Baker.

On motion of Charles W. Sherman, duly seconded, it was *voted* that the Executive Committee be authorized to appoint a standing committee on a system of sanitary scoring of water supplies.

J. A. Tremblay, Chief Engineer, Water Works Department, Quebec City, read a paper on "The Water Works of Quebec City." The discussion was participated in by Frank A. Winsor, G. C. Ham, M. N. Baker, George F. Merrill, and President Taylor.

The Secretary, Frank J. Gifford, submitted his annual report. (*See pages 281–284.*)

The Treasurer, Albert L. Sawyer, submitted his annual report. (*See pages 284–286.*)

The Editor of the JOURNAL, John P. Wentworth, submitted his annual report. (*See pages 288–290.*)

The report of the Finance Committee was read by George A. Sampson. (*See page 287.*)

Election of Officers.

The committee reported as follows:

President.

THEODORE L. BRISTOL, President Ansonia Water Company, Ansonia, Conn..... 281

Vice-President.

GEORGE A. CARPENTER, City Engineer, Pawtucket, R. I..... 279

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J. W. GRAHAM, Treasurer and General Manager, Portland Water District, Portland, Me..... 272

Treasurer.

ALBERT L. SAWYER, Water Registrar, Haverhill, Mass..... 272

PRESIDENT TAYLOR. Gentlemen: You have heard the report of the Committee announcing the election of Theodore L. Bristol as president, and the other officers as named.

Mr. Bristol, are you prepared to accept the election as president of the Association? (*Applause.*)

THEODORE L. BRISTOL. Mr. President and gentlemen: The President asked me to make a speech; he told me I would have to make one, and I told him I could not do it. If I had one I suppose I ought to ask the Secretary to read it. (*Laughter.*)

I want to thank you, gentlemen, very much for the honor. I have not any speech to make, except to express my thanks. I will do the best I can. I think I am very much handicapped because I know very few members of the Association or their qualifications, but I am going to try to find out about them and ask them to help me, and I hope those that I call on will help me.

I thank you again. (*Applause.*)

Evening Session.

A paper prepared by Col. Francis F. Longley, illustrated by lantern slides, entitled "The Coolgardie Pipe Line in Australia and Measures Taken to Correct Corrosion," was read, in the absence of Colonel Longley, by J. E. Longley; President Taylor and J. F. Laboon participating in the discussion. A written discussion of this paper, prepared by F. N. Speller, was read by the Secretary.

John F. Laboon of The J. N. Chester Engineers, Consulting Engineers, Pittsburgh, Pa., read a paper on "Features of the Wheeling, W. Va., Water Works Design and Operating Results," which was illustrated by lantern slides. Morris Knowles and Paul Hansen took part in the discussion.

PRESIDENT TAYLOR. I think we ought to place on record our appreciation of the services of Arthur D. Weston, who has so kindly loaned us and operated the lantern outfit, also of Arthur C. King, who has assisted

him. Mr. Weston has also been of great service in the preliminary arrangements for this Convention, and I think we should acknowledge our appreciation of his work. Unless there is some objection we will place on record a unanimous vote of thanks for the men mentioned.

FRIDAY, SEPTEMBER 11, 1925.

Upon arrival at Quebec, automobiles were taken for a trip about the city and to the water-works plant. Luncheon was served at the Chateau Frontenac, at which time the party was welcomed to Quebec by His Worship, Mayor Joseph Samson, and Chief of Police Emile Trudel.

After luncheon the party took an all-afternoon trip to Ste. Anne de Beaupré, stopping at the Falls of Montmorency on the return trip.

Evening Session.

A paper prepared by Caleb Mills Saville, Manager and Chief Engineer, Board of Water Commissioners, Hartford, Conn., on "Financing Main Pipe Extension by Assessment Method," was read, in the absence of Mr. Saville, by the Secretary. E. G. Bradbury, Frank J. Gifford, Morris Knowles, M. N. Baker, W. C. Hawley, and Theodore L. Bristol took part in the discussion.

A paper on "Fineness Modulus for Filtration Sands" was read by R. G. Tyler, Professor Sanitary Engineering, Massachusetts Institute of Technology. Paul Hansen discussed the paper.

PRESIDENT TAYLOR. Is there anyone who has any business which he desires to bring before the Association? This is the last time we will be together, and I want to take this occasion once more to thank you for the privilege of serving you as President the past year, and I am very much pleased to turn the affairs over to Mr. Bristol, my successor.

If there is no further business, we will now adjourn.

FRANK E. WINSOR. Mr. President: I assume the Secretary will follow the usual custom in conveying the thanks of the Association to the people of Montreal, Quebec, and to any others to whom we are indebted.

The PRESIDENT. I think that should be done. Proper acknowledgment should be made to those who have helped to make the Convention and trip a success. It added considerably to our pleasure to have the Mayor and the Chief of Police with us this noon.

EDWARD G. BRADBURY. It is very evident that somebody has done a lot of hard work in connection with this Convention, and I think we should express our thanks to the Committee in charge which has made the arrangements and prepared this very fine program for this meeting. I should like to move a vote of thanks.

MR. WINSOR. You mean the present officers?

MR. BRADBURY. The officers, of course.

(The motion was duly seconded and carried.)

PRESIDENT TAYLOR. We very much appreciate this expression of thanks. The credit is due to the whole Executive Committee, and perhaps Mr. Weston and Mr. Gifford have done most of the real hard work. For my part I have enjoyed it very much, and I think we all have.

If there is nothing further, we will adjourn.

Upon arrival of the S.S. *Richelieu* at Montreal on Saturday, September 12, automobiles were taken for a trip about the city, including a visit to the water-works plant. The party had luncheon at the Hotel Windsor. During the afternoon carriages were provided for a trip to Mount Royal. Dinner was also served at the Hotel Windsor, after which a special train was taken for Boston and other New England points.

ANNUAL REPORT OF THE SECRETARY.

Mr. President and Gentlemen of the New England Water Works Association, — The Secretary submits herewith the following report of the changes in membership during the past fiscal year, and the general condition of the Association.

The present membership is 751, constituted as follows: 7 Honorary, 654 Members, 2 Juniors, 84 Associates, and 4 Corporate Members, there being a net loss for the year of 7. The detailed changes are as follows:

MEMBERSHIP.

September 1, 1924.	Honorary Members	9		
	Died	2		7
September 1, 1924.	Total Members		665	
	Withdrawals:			
	Resigned	25		
	Dropped	37		
	Died	10	72	
			593	
	Elected:			
	Sept.-Oct., 1924	12		
	November, 1924	3		
	December, 1924	5		
	January, 1925	7		
	February, 1925	1		
	March, 1925	3		
	June, 1925	14	45	
	Reinstated:			
	Member dropped in 1919	1		
	Member dropped in 1920	1		
	Members dropped 1923-24	14	16	
				654
September 1, 1924.	Total Juniors		2	
September 1, 1925.	Total Juniors			2

September 1, 1924.	Total Associates		81	
	Withdrawals:			
	Resigned	2		
	Dropped	4	6	
			75	
	Elected:			
	September, 1924	2		
	December, 1924	1		
	March, 1925	1	4	
	Reinstated:			
	Resigned, 1919	1		
	Resigned, 1921	1		
	Dropped, 1920	1		
	Dropped, 1923–24	2	5	
				84
September 1, 1924.	Total Corporate Members		1	
	Elected:			
	Sept.–Oct., 1924	1		
	June, 1925	2	3	4
September 1, 1925.	Total Membership			751
September 1, 1924.	Total Membership			758
	Net loss			7

Members Elected from September 1, 1924, to September 1, 1925.

September 30 to October 3, 1924. F. L. Buckley, C. J. Clogston, M. J. Diven, Jr., P. J. Hughes, J. C. Harding, Jr., S. T. Lawry, R. E. Manson, J. M. Mead, G. N. Norris, R. S. Scott, V. B. Siems, H. U. Storrs. (12)

November 11, 1924. Philip DeWolf, H. H. Hitchcock, A. L. Shaw. (3)

December 9, 1924. S. E. Coburn, G. S. Deming, A. B. Mauzy, W. G. Schneider, R. G. Tyler. (5)

January 13, 1925. G. G. Gean, W. J. Burke, C. W. Ellis (Mattapoisett), M. M. Gibbons, F. Wm. Haley, C. R. Jones, P. R. Neff. (7)

February 10, 1925. Patrick S. Nugent. (1)

March 11, 1925. G. W. Coffin, E. C. Heacox, A. A. Ross. (3)

June 25, 1925. G. L. Covell, C. W. Ellis (Randolph, Vt.), G. Y. Gaillard, A. E. Griffin, N. LeRoy Hammond, T. W. Jenkins, Scott Keith, S. J. Kyle, A. C. Libby, W. B. Marden, P. H. Mosher, J. P. O'Connor, T. A. Rich, J. P. Miller. (14)

Reinstated:

Dropped in 1919. William J. Lumbert. 1

Dropped in 1920. James H. Reynolds. 1

Dropped in 1923–24. G. F. Ashton, S. S. Barden, F. J. Dixon, H. W. Dotten, W. D. Frederick, C. N. Harrub, P. E. Kelly, J. A. McMurry, C. W. Mills, E. E. Minor, J. D. Moore, L. H. Newhall, W. G. Newhall, Alexander Potter. 14

Corporate Members.

March 10, 1925. Fall River Water Board. (1)
June 25, 1925. Groton (Conn.) Board of Water & Light Comrs., Middletown (Conn.) Water Board. (2)

Associate Members.

September 30 to October 3, 1924. Cohoes Rolling Mill Co., Paradon Engineering Company. (2)
December 9, 1924. Dyar Sales & Machinery Co. (1)
March 10, 1925. James E. Williamson. (1)
Reinstated:
Resigned in 1919. Chicago Pneumatic Tool Co. (1)
Resigned in 1921. Public Works. (1)
Dropped in 1920. S. E. T. Valve & Hydrant Co. (1)
Dropped 1923–24. Badger Meter Mfg. Co., Van Gilder Water Meter Co. (2)

Honorary Members.

Died: Edwin C. Brooks, Willard Kent. (2)

Members.

Died: G. H. Benzenberg, M. F. Collins, J. M. Diven, C. W. Eddy, Robert Gardner, A. J. Jones, E. W. Kent, J. F. Reagan, Jr., G. G. Weeks, G. C. Whipple. (10)
Resigned: J. F. Barrett, G. E. Bragg, W. J. Burke, Bertram Brewer, B. R. Chapman, H. B. Collins, G. K. Crandall, C. B. Crowell, E. M. Craig, Jr., F. A. Dallyn, L. S. Doten, John Doyle, H. W. Green, D. R. Gwinn, J. E. Hill, C. A. Holden, P. J. Hughes. J. H. Mendall, W. A. Nial, W. J. Sando, F. D. Sayer, G. O. W. Servis, H. C. Stevens, G. A. Stowers, G. L. Watson. (25)

Associate Members.

Resigned: Chase Metal Works; Fields Point Mfg. Co. (2)

Receipts for Fiscal Year, September 1, 1924, to September 1, 1925.

Entrance Fees			$208.00
Annual Dues:			
Members	$3 531.95		
Juniors	6.00		
Associates	1 580.00		
Corporates	10.00	$5 127.95	
Fractional Dues:			
Members	$232.50		
Associates	73.02		
Corporates	5.00	310.52	
Advance and Back Dues		157.16	
Total Dues			5 595.63
Advertisements			4 178.00
Subscriptions			511.11
JOURNALS sold			65.25
Sundries			611.97
Total receipts			$11 169.96

There is due the Association:		
Advertisements	$266.00	
JOURNALS	27.75	
Reprints	73.40	
Subscriptions	40.00	
Total	$407.15	407.15
TOTAL		$11 577.11

Respectfully submitted,
FRANK J. GIFFORD, *Secretary.*

ANNUAL REPORT OF THE TREASURER.

September 1, 1924, to August 31, 1925.

The President and Members of the New England Water Works Association:

I herewith submit my report as Treasurer for the year ending August 31, 1925.

Receipts.

September 1, 1924 — Cash on hand			$640.41
Initiation fees	$208.00		
Dues	5 595.63	$5 803.63	
Interest and dividends		468.05	
JOURNAL:			
Advertisements	$4 178.00		
Subscriptions	511.11		
JOURNALS sold	65.25		
Sale of reprints	19.00	4 773.36	
Miscellaneous:			
Certificates of membership	$37.00		
Meter sheets	.30		
Membership lists	5.00		
Standard Specifications	5.25		
Exchange	.25		
Half balance a/c June outing	77.12	124.92	
			11 169.96
Total receipts			$11 810.37

Expenditures.

JOURNAL:		
Advertising agent's salary	$100.00	
Advertising agent's commission	16.00	
Editor's salary	300.00	
Editor's expense	13.00	
Plates	357.65	
Printing	3 955.91	
Reporting	289.97	
Reprints	290.08	
Stationery and postage	127.88	
Sundries	3.11	
		$5 453.60

Office:			
Affiliated Technical Societies	$2 000.00		
Printing, stationery and postage	153.14		
Secretary's salary	200.00		
Secretary's expense	107.56		
Sundries	7.94		
		2 468.64	
Meetings and Committees:			
Dinners for guests	$66.75		
Music at dinners	30.00		
Printing, stationery and postage	437.72		
Stereopticon	40.00		
Sundries	25.65		
		600.12	
Miscellaneous:			
Certificates of membership	$12.50		
Exchange	1.10		
Treasurer's salary and bond	62.50		
Sundries	63.77		
		139.87	
Total expenditures			$8 662.23
August 31, 1925. Cash on hand			3 148.14
			$11 810.37

Invested Funds.

Invested funds September 1, 1924	$8 622.43
Interest on bonds	120.00
Interest on deposit	41.77
Interest on savings bank deposits	306.28
	$9 090.48
Interest paid over to the Association	$468.05
Invested funds August 31, 1925	8 622.43
	$9 090.48

The report of the Treasurer last year showed cash on hand $9 262.84. In starting a new cash book I deemed it advisable to separate the reserve fund under the heading "Invested Funds," thus making the cash on hand as shown by this year's report, the actual balance available for the payment of bills.

The Finance Committee last year recommended a budget for 1924–25 of $9 700. There has been expended during the year $8 662.23, leaving an unexpended balance of $1 037.77. The details are as follows:

	Journal.	*Office.*	*Meetings.*	*Miscellaneous.*
Appropriation	$6 400.00	$2 550.00	$500.00	$200.00
Expended	5 453.60	2 465.64	602.12	140.87
Balance	$946.40	$84.36	*$52.12	$59.13

*Overdue.

Respectfully submitted,

ALBERT L. SAWYER, *Treasurer.*

TREASURER'S REPORT.

STATEMENT OF RECEIPTS AND EXPENDITURES.

Receipts.		*Expenditures.*	
Cash on hand Sept. 1, 1924	$640.41	Bills paid as per vouchers	$8 662.23
Interest on bonds and deposits	468.05	Cash on hand Aug. 31, 1925	3 148.14
Received from Secretary	10 624.79		
Half balance of June outing	77.12		
	$11 810.37		$11 810.37

ASSETS AND LIABILITIES.

Assets.			*Liabilities.*	
Cash in banks as per list		$9 955.57	Surplus	$12 177.72
Old Colony Trust Co.	$3 148.14			
Farmers and Mechanics Savings Bank, Framingham	2 068.46			
Franklin Savings Bank	2 000.00			
Home Savings Bank	1 011.25			
Mechanics Savings Bank	261.19			
People's Savings Bank	1 466.53			
Bonds Nos. 2642 and 2644 Lake Shore & Michigan So. R.R. 4's, due May 1, 1931		1 815.00		
Accounts Receivable:		407.15		
Advertisements	266.00			
JOURNALS	27.75			
Subscriptions	40.00			
Reprints	73.40			
		$12 177.72		$12 177.72

The foregoing accounts have been audited and found correct.

GEORGE A. SAMPSON,
RICHARD H. ELLIS,
DWIGHT L. AGNEW,
Finance Committee.

REPORT OF FINANCE COMMITTEE.

September 2, 1925.

Executive Committee,
New England Water Works Association.
Gentlemen:

The Finance Committee submits the following budget for the fiscal year ending August 31, 1926:

JOURNAL printing	$5 000
JOURNAL miscellaneous	1 900
Office	2 800
Meetings and Committees	700
Miscellaneous	200
	$10 600

In making an estimate of the receipts available for the budget, it has been assumed that the membership of the Association will be the same as during the past year, although it is hoped that an increase in membership may be secured.

The amount to be paid to the Affiliated Technical Societies of Boston is $1 950, which is a reduction of $50 from the last fiscal year.

An allowance in office expenditures of $275 has been made for printing a new list of members and constitution during the fiscal year, as the last issue was for the year 1923–1924.

The budget allows $5 000 for printing the JOURNAL, which is an increase of about $1 000 over the actual expenditure for this item during the past year, as it is hoped that the size of the JOURNAL may be increased 25 per cent. in 1925–1926. $1 900 is allowed for JOURNAL miscellaneous, making a total of $6 900. It is believed that of this amount at least $4 000 will be received from advertising.

It is evident from the reports of the Secretary and Treasurer that a considerable surplus has accumulated during the past few years, which ought to be reflected in a larger JOURNAL and an increased membership.

Yours very truly,

GEORGE A. SAMPSON,
RICHARD H. ELLIS,
DWIGHT L. AGNEW,
Finance Committee.

Annual Report of the Editor.

To the New England Water Works Association: The Editor submits herewith the following report for the year ending August 31, 1925.

As has been customary in the past, the tables of financial figures, accompanying the report, are based upon total charges and accounts receivable, rather than actual cash received or disbursed.

Table 1 is a statement of the material published.

Table 2 gives the receipts and expenditures for the year.

Table 3 is a comparison of the JOURNAL for the past year with preceding years.

Size. The four issues contained 644 pages, of which 421 were text.

Cost. The gross cost of the JOURNAL was $5 272.91, equivalent to $6.98 per member, and the net cost was $943.40, equivalent to $1.25 per member.

Reprints. Fifty reprints of each paper have been furnished to the author where desired.

Circulation. The present circulation of the JOURNAL is:

Members, all grades	751
Subscribers	107
Exchanges	15
Total	873

(JOURNALS have been sent to all subscribers.)

Respectfully submitted,

JOHN P. WENTWORTH, *Editor.*

EDITOR'S REPORT.

TABLE 1.

STATEMENT OF MATERIAL IN SEPTEMBER AND DECEMBER, 1924, AND MARCH AND JUNE, 1925, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Date.	Pages of								
	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates.	Total.	Total Cuts.
September, 1924..	98	19	117	0	48	5	2	172	25
December, 1924..	119	3	122	6	48	5	0	181	0
March, 1925.....	100	3	103	0	48	5	3	159	32
June, 1925.....	79	0	79	0	48	5	0	132	27
Total.....	396	25	421	6	192	20	5	644	84

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF SEPTEMBER AND DECEMBER, 1924, AND MARCH AND JUNE, 1925, ISSUES OF JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Receipts.		*Expenditures.*	
Advertisements	$3 737.00	Advertising agent's salary and commissions.....	$116.00
Sale of JOURNALS.....	93.00	Plates.....	357.65
Reprints.....	92.40	Printing.....	3 775.22
Subscriptions.....	407.11	Reporting.....	289.97
	$4 329.51	Mailing and postage.....	127.88
Net cost of JOURNAL.....	943.40	Editor's salary.....	300.00
		Editor's incidentals.....	13.00
		Reprints.....	290.08
		Sundries.....	3.11
	$5 272.91		$5 272.91

EDITOR'S REPORT.

TABLE 3.

COMPARISON OF JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1916.	Vol. XXXII. 1918.	Vol. XXXIII. 1919.	Vol. XXXIV. 1920.	Vol. XXXV. 1921.	Vol. XXXVI. 1922.	Fiscal Year Ending Aug. 31, 1924. 4 issues.	Fiscal Year Ending Aug. 31, 1925. 4 issues.
Average edition (copies printed)	1 050	1 325	1 500	1 388	1 200	1 130	1 150	1 100	1 100	1 100
Average membership	803	904	1 002	954	902	885	864	826	764	755
Circulation at end of year	951	1 079	1 155	1 010	1 002	970	929	929	880	873
Pages of text	564	596	538	398	566	359	399	618	404	421
Pages of text per 1 000 members	702	659	538	417	627	406	462	748	529	558
Total pages, all kinds	719	776	707	557	726	520	560	801	611	644
Total pages per 1 000 members	895	859	707	584	805	588	648	970	800	853
GROSS COST:										
Total	$3 345.87	$4 243.35	$3 386.63	$3 115.00	$4 967.99	$5 011.03	$5 381.84	$6 354.10	$4 783.60	$5 272.91
Per page	4.65	5.47	4.79	5.59	6.84	9.64	9.61	7.93	7.83	8.19
Per member	4.17	4.68	3.38	3.26	5.51	5.66	6.23	7.69	6.26	6.98
Per member per 1 000 pages	5.80	6.02	4.79	5.85	7.59	10.88	11.12	9.60	10.25	10.84
Per member per 1 000 pages text	7.39	7.85	6.30	8.19	9.74	15.77	15.61	12.47	15.50	16.58
NET COST:										
Total	$1 155.33	$1 091.09	$1 171.98	$694.54	$2 675.04	$1 722.14	$1 869.85	$2 434.26	$561.51	$943.40
Per page	1.61	2.70	1.65	1.25	3.68	3.31	3.34	3.04	0.92	1.46
Per member	1.44	2.32	1.17	.73	2.97	1.95	2.16	2.95	0.74	1.25
Per member per 1 000 pages	2.00	2.98	1.65	1.31	4.09	3.75	3.87	3.68	1.20	1.94
Per member per 1 000 pages text	2.38	3.88	2.17	1.83	5.25	5.43	5.43	4.77	1.82	2.97

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ENGINEER'S SECTION

FULLER & McCLINTOCK
Engineers
NEW YORK, 170 Broadway
PHILADELPHIA, PA., 1001 Chestnut St.
TOLEDO, OHIO, Summit-Cherry Bldg.
KANSAS CITY, MO., Walsix Bldg.
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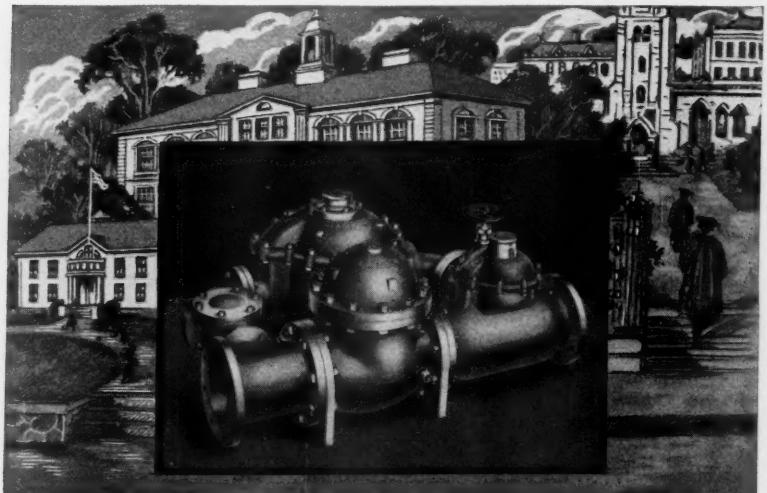
FRANK J. GIFFORD, *Sec'y,*
715 Tremont Temple, Boston, Mass.

Dear Sir: Enclosed please find $\frac{\$.75}{1.50}$ in payment of charge for Certificate of Membership in the N. E. W. W. Association ($\frac{2.25}{\$1.50}$), and Membership Button ($1.00), which please mail me and oblige

Yours truly,

CONTRACTORS

G. FERULLO COMPANY
General Contractors
Specializing in Water Works
31 NORTH SQUARE
BOSTON, MASS.
Telephone, Richmond 1200



287,804 SCHOOL BUILDINGS

are worth less than half the value of the property this Meter protects

THE HERSEY DETECTOR METER is installed on fire services protecting nearly $5,000,000,000 worth of property, or a sum over 50% in excess of the value of the 287,804 school buildings in the United States.

Not theory but the practical experience of 20 years has gained the unrestricted acceptance of the Hersey Detector Meter for every kind of fire service by every insurance company, stock and mutual, in the country and more than 800 water departments and water companies.

This record has no equal.

HERSEY WATER METERS

HERSEY Manufacturing Company

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FROZEN!—but not damaged

Here is an actual photograph of a LAMBERT Frost-proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

The expense and annoyance from frozen water meters can be eliminated for all time through the installation of the LAMBERT Frost-proof.

It has been proved that the LAMBERT is the easiest water meter to take apart and put together again as well as the simplest, most reliable and accurate.

If you are interested in other types of meters, we make one for every requirement.

THOMSON METER COMPANY

100-110 BRIDGE STREET BROOKLYN, N. Y.

LAMBERT FROST-PROOF METERS

MECHANICAL PERFECTION

AN entirely automatic mechanism combining every attribute essential to performance in operation over a long period of years—this is the earned reputation that has prompted hundreds of cities, both small and large, to specify Neptune Trident Meters.

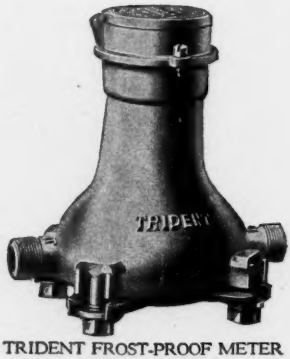
Since the first Neptune Trident Meter was designed and constructed, the one purpose has been to produce (at reasonable cost) the best meter that can be made. Any entirely mechanical unit to function properly for years, without frequent repairs and replacement of parts, must be as near perfection as is possible. Trident Meters are without comparison in durability and the perfect functioning of working parts—because of designing that has met the universal approval of water engineers, the use of only first grade materials, and precision methods of manufacture that must pass 100 per cent inspection.

Irrefutable proof of Trident supremacy is the fact that more than 2,750,000 have been installed, many of which have given unfailing accuracy in constant use for over thirty years.

It will prove profitable to you to study the results in any city where Trident Meters are in service.

AQUAFAX is a 56-page, monthly magazine giving current news and accurate information regarding the conservation of water. The regular subscription price is $3.00 per year, but it will be sent free upon request to engineers, municipal heads and civic organizations.

Send for a copy of the 86-page book illustrating and describing all types and sizes of Neptune Trident Meters.



TRIDENT FROST-PROOF METER

The Breakable Bottom positively prevents damage to the meter through freezing.

TRIDENT SPLIT-CASE METER

A special type designed to adequately meet the requirements in a warm climate.

NEPTUNE METER COMPANY

Pioneers in Meter Progress

50 EAST FORTY-SECOND STREET, NEW YORK CITY

NEPTUNE METER CO., LTD., 1197 KING ST., WEST, TORONTO, ONT.

Boston	San Francisco	Los Angeles	Portland
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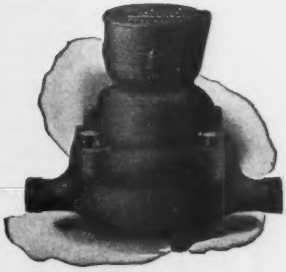
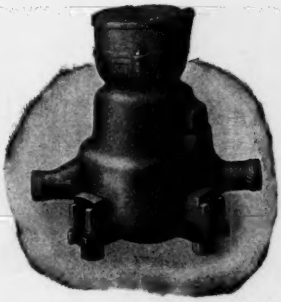
WATER METERS

The TROPIC — An all-bronze Water Meter, with connection spuds attached to the lower case. Particularly designed for warm sections of the country.



TROPIC



ARCTIC

The ARCTIC — A frost-bottom meter, especially designed for cold sections of the country.

These two meters embody exactly the same mechanical features, the only difference being the changes necessary to provide a frost breaking feature in the Arctic.

Either of these meters will be equipped with a COMPLETELY ENCLOSED intermediate train RUNNING IN OIL, if desired.

Write or wire nearest office for full information.

Please Note Change of Address

PITTSBURGH METER COMPANY

7800 Susquehanna St., Pittsburgh, Pa.

SALES OFFICES:

New York, 50 Church Street
Chicago, 5 So. Wabash Avenue
Kansas City, Mutual Building
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Seattle, Washington
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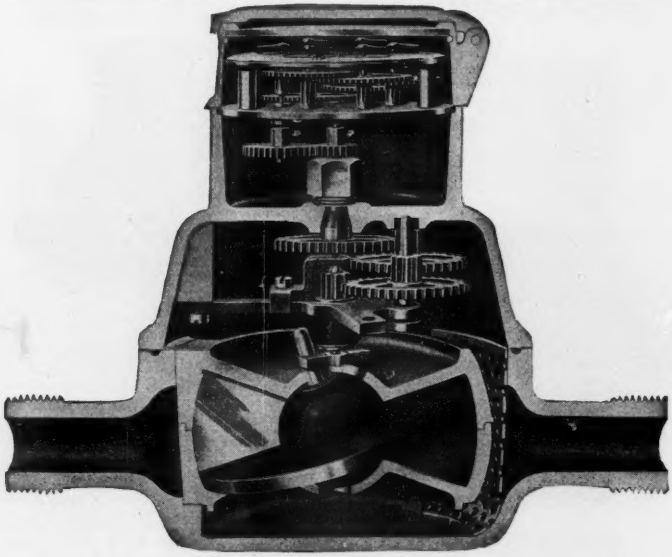
Metered water service and *sustained accuracy*



METERED water service means equitable charges, less pumpage, less expense, less investment in pumping equipment and more reserve capacity; but to realize these advantages it is essential that the meters be accurate, reliable and easy to maintain in operating condition.

The Worthington Type G Meter fulfills all these requirements. It has few parts and low friction losses. Its construction is staunch and simple, requiring only slight and inexpensive repairs at long intervals. The wearing parts have the slowest motion of any meter manufactured. The disk is water balanced and reinforced. Precautions are taken against corrosion by using bronze and Monel metal in the construction.

The intermediate gear train is located directly in the path of the water flowing through the meter which results in these parts being constantly swept clean of all sedimentation. All bearings and supports are exceptionally strong and substantial. Any gear may be replaced without replacing the entire gear train. The register mechanism is compact, extremely rigid and bushed completely with rubber.

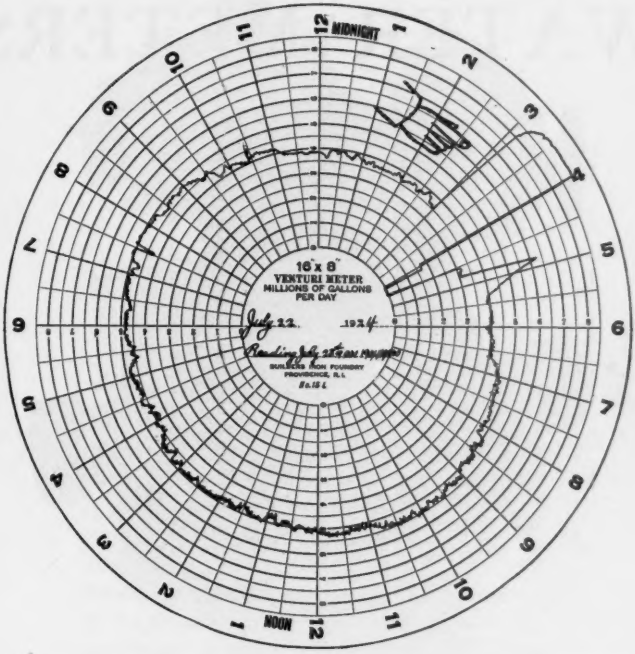
Freezing can be rendered harmless in the $\frac{5}{8}$, $\frac{3}{4}$ and 1 inch sizes by use of special frost clamps.

WORTHINGTON PUMP AND MACHINERY CORPORATION
115 BROADWAY, NEW YORK CITY BRANCH OFFICES IN 24 CITIES

WORTHINGTON

5133-1

3 O'CLOCK IN THE MORNING



AT exactly 3 o'clock in the morning of the 22nd a hydrant suddenly blew off from the main pipe line in Newport, Ky. For one hour the water tore up the street at high velocity before the district could be finally shut off.

At 4.30 the water was turned on again and the city's line refilled. At 5.30 the 16-in. Venturi Meter on the main supply line between Covington and Newport showed normal flow restored.

The Venturi Chart Record immediately tattled the entire tale to the superintendents of both water departments.

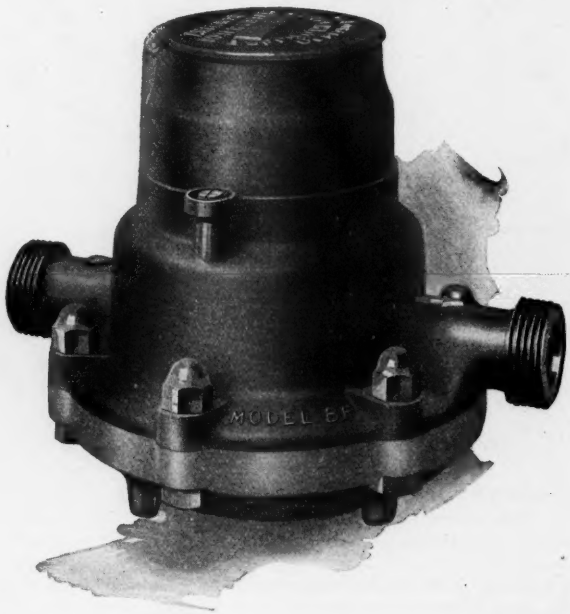
Waterworks Systems Need Venturi Dependability

BUILDERS IRON FOUNDRY

PROVIDENCE, R. I.

VENTURI

AMERICAN AND NIAGARA
WATER METERS



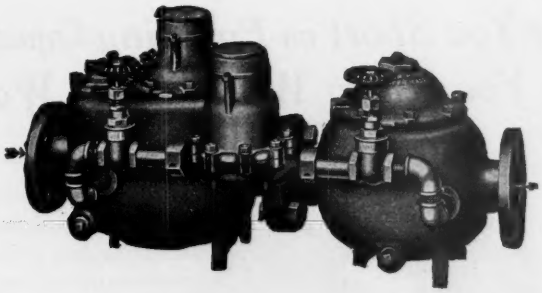
American and Niagara meters are made in solid casing types and frost bottom types. The illustration above shows a $\frac{5}{8}$" x $\frac{3}{4}$" meter of the frost bottom type. Those meters having bronze outside casings are known as Americans and those having galvanized cast-iron outside casings are Niagaras. The works in all the different casings are of one best model and interchangeable. The registers may be either round reading or straight reading and may indicate cubic feet, U. S. gallons, imperial gallons or litres. All Niagara and American meters are tested and adjusted according to the requirements of the Standard Specifications for water meters adopted by the New England Water Works Association and the American Water Works Association.

Write for large catalog and prices.

BUFFALO METER CO.

ESTABLISHED 1892

2896 Main Street **BUFFALO, N. Y.**



The New Nilo

The new improved **Nilo Compound Meter** now comes equipped with a bronze body. This is a valuable addition to meter service for it eliminates the danger of corrosion and filling up due to the collecting of corrosive matter. Bronze being stronger than iron the gross weight of the meter is less, making it easier to transport, handle and install.

It also has two gate valves which allow the removal of the by-pass meter for cleaning or repairing without shutting off the line.

The controlling valve mechanism of the new **Nilo Compound Meter** is self contained and easily detached from the main body casings.

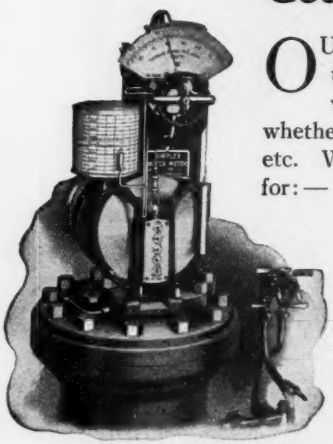
These three improvements make the **Nilo,** a long standing favorite, the unrivaled leader in its field.

UNION WATER METER CO.

Incorporated 1868

WORCESTER, MASSACHUSETTS

Is Your Pressure Low?
Are You Short on Pumping Capacity?
Do You Know Where Your Water Goes?



OUR Engineering Department will tell you how to determine your water distribution, how to find out whether or not new mains are required, etc. We can supply you with the means for:—

1. Checking up pump performance and determining slippage due to leaky plungers, defective valves, short stroking or other causes,
2. Measuring delivery of centrifugal pumps and figuring whether or not the station is up to efficiency,
3. Distributing proportionately the cost of water supplied to several districts,
4. Checking up the performance of filter beds,
5. Detecting waste or pipe leakage,
6. Recording daily amounts of sewage handled and planning future extensions, etc., etc.

THE SIMPLEX METER

VENTURI, PITOT TUBE OR ORIFICE TYPES

THE importance of exact measurements by means of a Simplex Meter cannot be over emphasized. Mr. Jeffries, Chairman of the West Chester, Pa. Water Works Committee, was able, by checking the performance of his pumping engine with a Simplex Meter, to discover that due to the imperfection and wear in the valves the slippage amounted to 300,000 gallons of water per day. This represented a daily loss of $30.00, or in other words a daily saving of $30.00, or $900.00 per month, when the valves were put in order. The Simplex Meter thus paid for itself in a month's time.

Frequent repeat orders from satisfied customers who formerly used other meters are the best evidence of merit of the Simplex Meter.

We have had many years' experience in solving water flow problems involving all sorts of conditions, and we are at all times prepared to submit general layouts involving cost and capacity, and to make explicit and complete recommendations. Write for Bulletin N26.

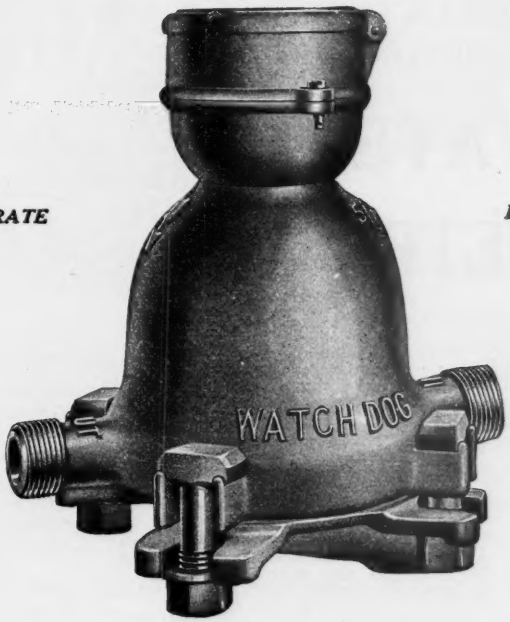
SIMPLEX VALVE AND METER COMPANY

Manufacturers of Meters for Water, Sewage, and Other Liquids, Rate Controllers, Automatic Air Valves, Regulating Valves, and Hydraulic Apparatus of Special Design.

6757 UPLAND STREET PHILADELPHIA, PA.

"WATCH DOG" WATER METERS

ACCURATE *DURABLE*



DISC, CURRENT AND COMPOUND TYPES

Inquiries Solicited

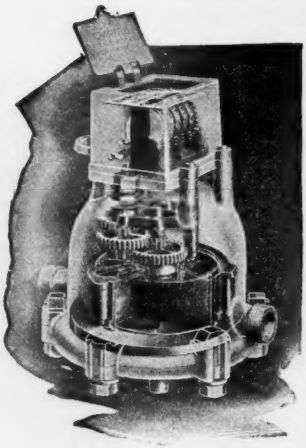
GAMON METER COMPANY

NEWARK **NEW JERSEY**

EMPIRE

OSCILLATING PISTON

WATER METERS



The design of the EMPIRE is entirely different from that of any other type. The easy "floating" motion of the oscillating piston, its balanced pressures, and light contact with the chamber walls, all combine to give this meter the unsurpassed accuracy and endurance that have made it famous for over forty years.

REVENUE EARNING

EMPIRE meters will register more closely on very small streams than any other meter. They will also produce greater net revenue, on account of their remarkably low upkeep cost. Ten, fifteen, even twenty years in active service, without the need of a single repair, are typical EMPIRE records.

Let us send you our new EMPIRE pamphlet, fully describing the meter and its operation, with illustrations of all styles. Ask for Circular No. 300.

NATIONAL METER COMPANY

299 BROADWAY, NEW YORK

New England Office, 287 Atlantic Ave., Boston, Mass.

Chicago Cincinnati Atlanta San Francisco Los Angeles

There is a complete line of Badger Water Meters from the small 5/8" disc type to the large 6" Turbine Compound. You will find a type and size Badger for every service.

The Proven Water Meter

You can conscientiously specify Badger Meters and be assured that they will perform dependably and accurately day after day. They have been tried, tested and have proven themselves. That is why they are being used in ever increasing numbers, the country over.

Badger Meters give satisfactory service because they are carefully constructed. They are intended to give long life, and they do.

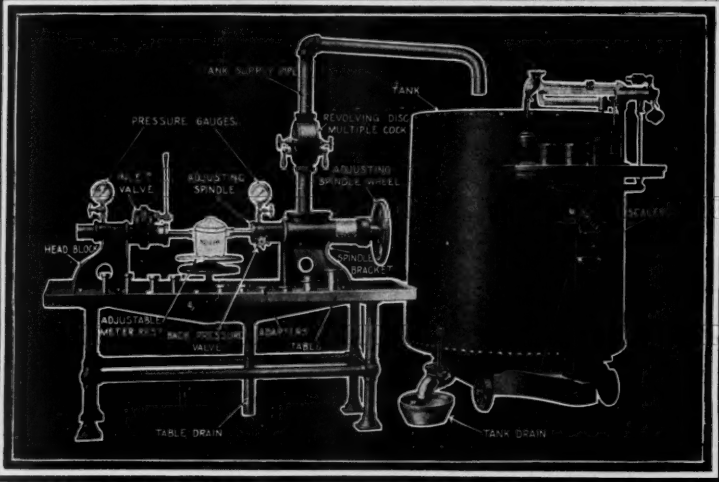
We are always glad to render advice on meter systems and stand ever ready to demonstrate the superiority of Badger Meters — theoretically, structurally, mechanically and practically. Let us send you special circulars giving detailed information.

Badger Meter Mfg. Co., 853 30th St., Milwaukee, Wis.

111 W. Washington Street, Chicago, Ill. 367 Fulton Street, Brooklyn, N. Y.
414 Interstate Bldg., Kansas City, Mo. 1621-39 Fifteenth Street, Denver, Colo.
4038 Arcade Bldg., Seattle, Wash.

BADGER METERS

"Faithful to the last drop"



The People Demand Increased Efficiency

You can make sure your Department gets full revenue for every gallon of water used—by seeing that all meters are regularly tested for accuracy—with the

Mueller Water Meter Tester

The Mueller will prove exactly what each meter does—will enable you to adjust each meter to absolute accuracy—will save more than its cost year after year. Used and endorsed by leading municipalities. The name Mueller guarantees both Quality and Service.

Detailed description and prices on request.

MUELLER CO., Decatur, Illinois

Phone Bell 153—Auto 2131

Water, Plumbing and Gas Brass Goods

New York City, 145 W. 30th St. — Phone, Madison Square 5397

San Francisco, 589 Mission St. — Phone Sutter 3577

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ATTENTION
WATER WORKS
OF NEW ENGLAND

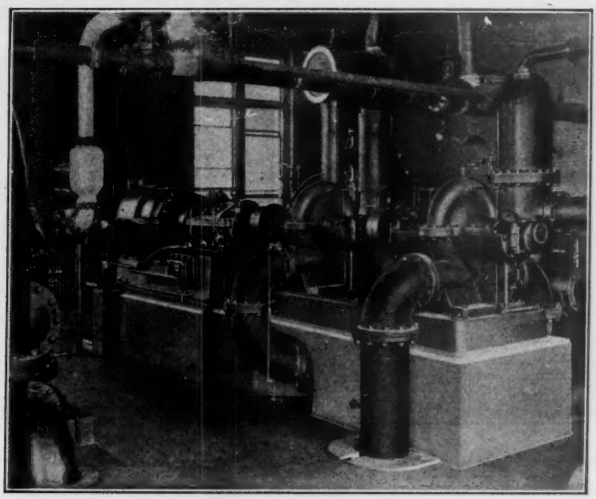
A few reasons why we solicit your inquiries on Water-Works Pumping Equipment:

First. — We make a specialty of furnishing Complete Water-Works Pumping Units of all types.

Second. — Total responsibility of installation is assumed by us.

Third. — We relieve the purchaser of every detail and turn the complete unit over to him under actual operation and with guarantee.

Fourth. — Every unit installed to date has exceeded its guarantee and has been completely accepted.



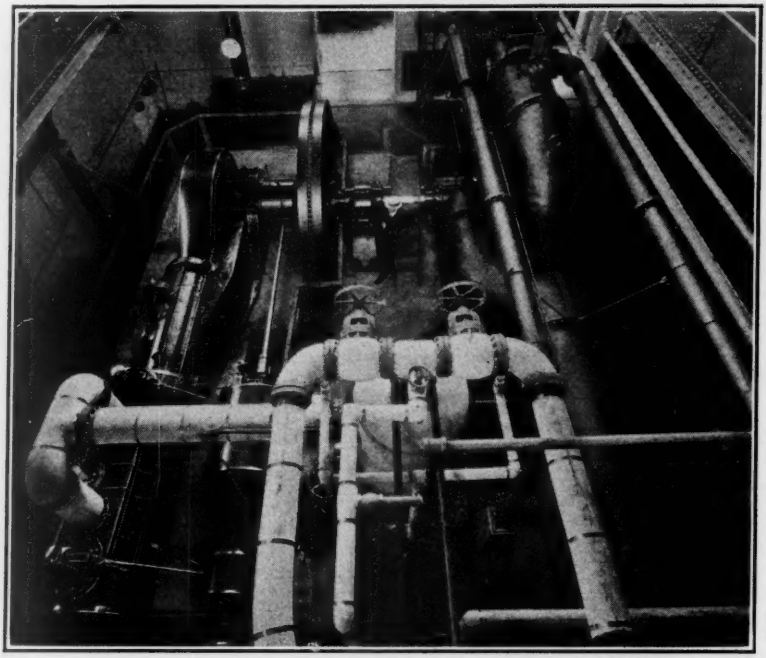
Turbine-driven Pump at the Arlington Station of the Metropolitan Water Works, Boston, Mass.

F. A. Mazzur & Co.

141 MILK STREET, BOSTON

A Notable Pump Installation at Ward Street, Boston

FOR METROPOLITAN DISTRICT COMMISSION



View of 36″ Morris Machine Works Pump with direct connected 24″ x 40″ Nordberg Uniflow Engine. This unit delivers 50,000,000 gallons per 24 hours against 45 feet dynamic head at 150 rpm. Duty Guarantee 107,000,000 foot lbs. per 1000 lbs. of dry saturated steam used at 150 lbs. pressure and with 4″ absolute vacuum.

The complete equipment including condenser, primary heater, special valves and fittings furnished under one contract and responsibility and to the direction of Mr. F. D. Smith, Engineer of the Metropolitan District Commission.

Starkweather & Broadhurst, Inc.

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HAYES PUMP AND MACHINERY CO.

94 PEARL ST., BOSTON, MASS.

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CENTRIFUGAL, POWER, STEAM PUMPS

STEAM TURBINES
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ELECTRIC MOTORS
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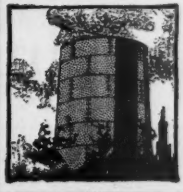
RAY ENGINEERING COMPANY
136 FEDERAL STREET
Boston, Mass.

Power Plant Equipment
Steam and Heating Specialties

For new pumping equipment guaranteed by people who will make good, phone, wire or write the above.
Sales Agents for UNION STEAM PUMP CO.



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Water Tanks
Gas Holders
and all other metal surfaces need the protection of
DIXON'S
Silica-Grap hite
PAINT
BOOKLET NO. 67-B
JOSEPH DIXON CRUCIBLE CO. Jersey City, N. J.

WE announce our appointment as Sales Representatives of DAYTON-DOWD COMPANY, of Quincy, Ill., Manufacturers of Centrifugal Pumping Machinery. After exhaustive investigation, we present this line of equipment to the Trade in New England as being of the highest grade and thoroughly modern in design and manufacture.

We are prepared to furnish DAYTON-DOWD pumps in all sizes and for all classes of service, in steam, motor, gasoline and belt drive types, and solicit your inquiries, assuring you of our best efforts in your sales and service requirements, and of our appreciation of your continued confidence and patronage.

POWER EQUIPMENT CO.

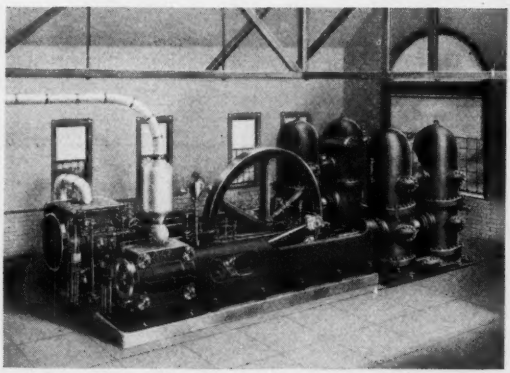
131 State Street, **Boston, Mass.**

MURRAY IRON WORKS CO.

(INCORPORATED 1870)

BURLINGTON, IOWA, U. S. A.

Builders of High Duty Pumping Engines



Murray High Duty Crank and Fly Wheel Pumping Engine, Opposed Type

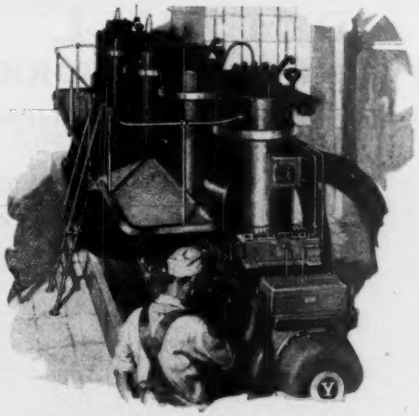
Engineers, Iron Founders, Boiler Makers

Corliss and Una-Flow Engines

Water-Tube, Fire-Tube and Internal-Furnace Boilers

Builders of Complete Power Plants

PLEASE SEND US YOUR SPECIFICATIONS AND CALLS FOR BIDS



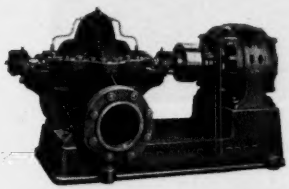
More than 90,000 h.p. *in Pumping Stations alone*

Over 90,000 horsepower of Type "Y" Engines are today furnishing power for pumping stations and the number is constantly increasing.

This steady change to Type "Y" Diesel power is the natural result of operation economies that have been accomplished during the past ten years.

In waterworks service, the Type "Y" Diesel effects a saving of 50 to 75 per cent of the cost of steam or purchased power — with absolute dependability and less attention than is required in operating a steam plant.

The Type "Y" Diesel is a 2-cycle valveless airless injection cold starting engine — actually simpler than even a slide valve steam engine.



More than 800,000 horsepower of Fairbanks-Morse oil engines are in daily operation in industrial, central station, and marine service. This unequaled acceptance points not alone to the economy of Diesel power but to the proved dependability of the Fairbanks-Morse Type "Y" Engine.

And the pumps, too, should be Fairbanks-Morse.

Just as electric motor development took a great step ahead when Fairbanks-Morse originated ball bearing motor construction, so the use of ball bearings in the new "Fig. 850" and "Fig. 870" Fairbanks-Morse Pumps has paved the way to higher pumping efficiencies and new economies. This is simply representative of the advanced construction that is found in Fairbanks-Morse Pumps for practically every duty. Centrifugal or piston types; motor, steam or oil engine drive: gear driven, belt driven, or direct-connected.

One of our engineers will gladly give you facts and figures. Detailed information on Diesel Engines, Pumps, or combined units, will be mailed on request.

FAIRBANKS, MORSE & CO., Boston

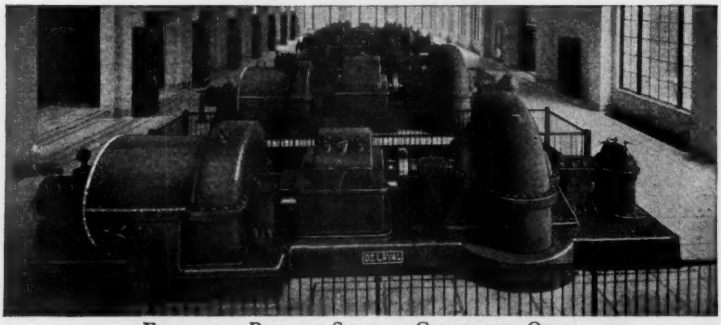
Manufacturers Oil Engines, Pumps and Electrical Machinery

Twenty-eight branches in the United States, each with a service station.

FAIRBANKS-MORSE
Diesel Engines - Pumps

DE LAVAL
CENTRIFUGAL WATER WORKS PUMPS

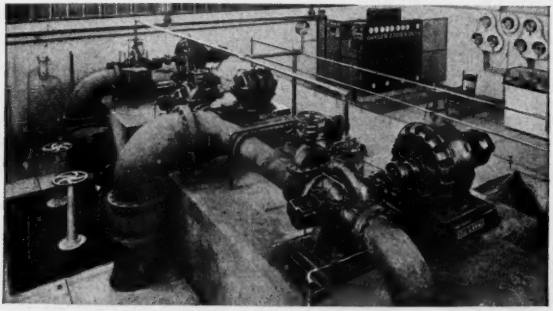
Supply 200 American Municipalities with over 5,000,000,000 gallons daily.



FAIRMOUNT PUMPING STATION, CLEVELAND, OHIO.

The largest Turbine driven pumping station in the United States. Total capacity 300 million gallons per day against heads from 85 ft. to 400 ft.

Cleveland has thirteen units installed totalling 600 million gallons per day. A fourteenth unit on order will have the unprecedented capacity of 60 million gallons against 270 ft. maximum head. Chicago has fourteen DE LAVAL units installed and on order totalling nearly 900 million gallons per day.



A TYPICAL SMALL DE LAVAL STATION, BROCKTON, MASS.

The De Laval Company announces their New England representation was transferred January 15, 1925, to

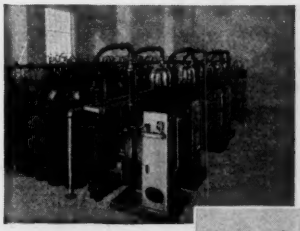
TURBINE EQUIPMENT CO. of NEW ENGLAND
CHAMBER OF COMMERCE BUILDING
80 Federal St., Boston

This company is under the direction of F. R. C. Boyd, President, who has been connected with De Laval representation in New England for over fifteen years.

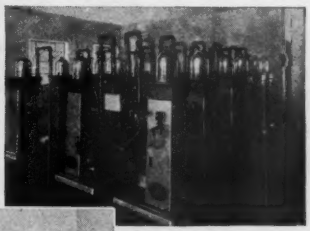
Ask for De Laval Publication.

DE LAVAL STEAM TURBINE COMPANY
Trenton, N. J.

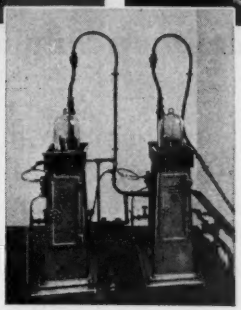
Chlorine in Sewage Purification



At the Westerly Sewage Disposal Works at Cleveland, six Pedestal Type Chlorinators are installed to chlorinate the Imhoff Tank Effluent.



Eighteen Pedestal Type Chlorinators installed at the Easterly Sewage Disposal Works, Cleveland, Ohio. "The Largest Chlorinator installation in the World." Capacity six and one-half Tons of Liquid Chlorine a day.



New York City uses the Pedestal Type Chlorinator at the Midland Beach Sewage Disposal Plant.

NOT ONLY has the Chlorination of water become standard practice in a large portion of the world but the value of Chlorine in Sewage Purification as a germicide, deodorant, and oxidizing agent is increasingly evident.

Sanitarians recognize that disease laden sewage should not be discharged into water used for drinking or bathing until the harmful germ life in the sewage has been destroyed.

Here W&T apparatus is particularly applicable. We invite inquiries concerning the use of our equipment in the Purification of Sewage.

"The only safe Water is a Sterilized Water"

TECHNICAL PUBLICATION NUMBER 42 "CHLORINE IN SEWAGE PURIFICATION" WILL BE MAILED ON REQUEST

WALLACE & TIERNAN
COMPANY, INCORPORATED
Manufacturers of Chlorine Control Apparatus
NEWARK NEW JERSEY

Founded 1853 Incorporated 1863

MERRIMAC CHEMICAL 1863 COMPANY

FILTER ALUM

Aluminum Sulphate

A basic, uniform product which has been used successfully by the leading water filtration plants in New England for many years.

Our location and shipping facilities place us in a position to offer insurpassable service and make us the logical source of supply for all filter plants in New England.

The aid and advice of our technical staff has often proved of great value to our customers. It is always at their service.

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Works:

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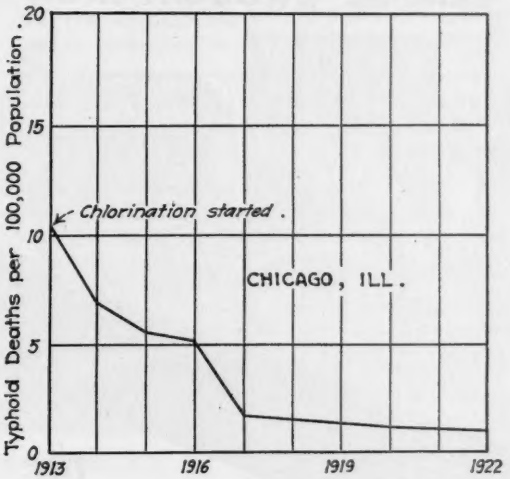

DIAGRAM SHOWS REDUCTION IN TYPHOID FEVER DEATH RATE AFTER INSTALLATION OF CHLORINE

Ask for

WHITE MOUNTAIN BRAND LIQUID CHLORINE

LINDER & MEYER

ESTABLISHED 1848

89 STATE STREET, BOSTON, MASS.

Selling Agents for

THE BROWN COMPANY

BERLIN, N. H.

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GENUINE WROUGHT IRON

the Spiral Stripe on every length of Byers pipe

A VERY plain spiral stripe now distinguishes all Byers Pipe from other pipe.

The spiral stripe, in red, yellow or other color, fills a long felt need for a conspicuous identifying mark, preventing mistakes and substitution of cheaper pipe.

Name and Year Also

As heretofore, the Byers name and two figures indicating year of manufacture, will be rolled in the pipe metal. The presence of these roll marks will, in all cases of doubt, furnish indisputable evidence of identity.

Byers genuine wrought iron pipe has a decided advantage in being highly resistant to corrosion. But because it looks exactly like cheaper pipe made of steel, substitution always has to be guarded against.

Literature on Request

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PITTSBURGH, PA. Established 1864

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Everything for the Water Works
MATTOON, ILLINOIS
Write for Catalogue No. 24

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SUCCESSORS TO
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JOBBERS OF
Heating and Plumbing Supplies
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Water Works Materials
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Byers Genuine Wrought Iron Pipe
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With Specially Adapted Lead-lined Fittings
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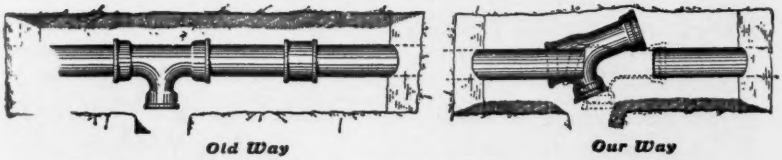
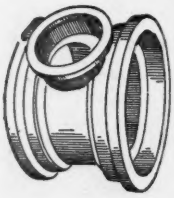
HYDRAULIC VALVES and MACHINERY

Cast Iron Pipe

CUTTING-IN TEES



Old Way *Our Way*



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

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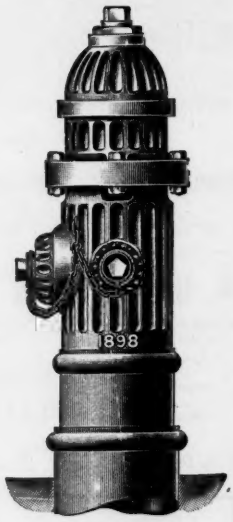
Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.



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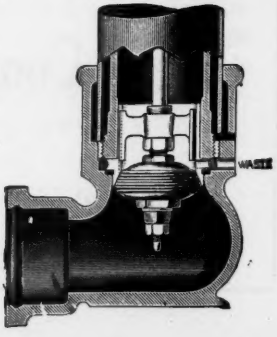
A half century of use has established their reputation as being the most economical, durable and simple hydrant.

Number in use exceeds total of all other makes combined.



Gate Valves

R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
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In every water works service

Kennedy Valves have demonstrated their dependability and economy of operation in every water-works service. In aqueducts, pumping stations and house supply systems all over the country, Kennedy Valves, ranging in size from hydraulically-operated gates large enough to handle the entire water supply of a city like San Francisco to little quarter-inch globe valves, are in wide use. New York, Chicago, St. Louis, Boston, Cincinnati, are but a few of the many cities that have learned the security of dependence on Kennedy Valve Control. Write for catalog describing the distinctive features of Kennedy Valves.

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WATER
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We make **Pressure Regulating Valves** for all purposes, steam or water.

Our **Feed-Water Filter** will keep oil out of your boiler.

We can interest you if you use a condenser.

Water Engines for Pumping Organs

THE ROSS VALVE MFG. CO.

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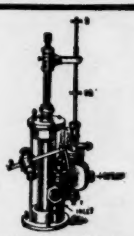

Standard for pumping church or parlor organs. Ask your organ builder for it or write us.

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Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

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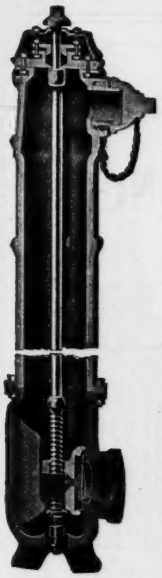

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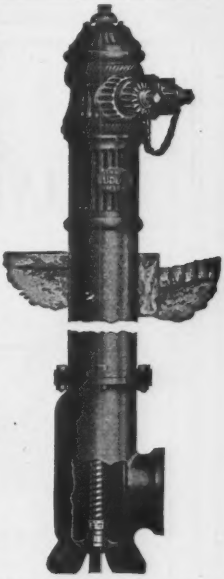
MANUFACTURERS OF

VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.



DOUBLE AND SINGLE GATE **VALVES,**

ALSO CHECK **VALVES,**

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YARD, WASH, AND FLUSH **HYDRANTS.**

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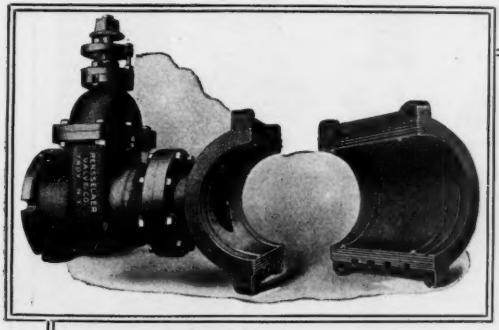

Rensselaer Tapping Sleeves

were brought out to meet a growing demand for a "BETTER" Tapping Sleeve. They were designed to suit conditions met in actual practice.

They can be used with all standard makes of Tapping Machines.

POINTS OF
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Have two lead rings.

Require less lead for calking.

Iron washers not required.

Bolting flanges are made full length of sleeve, giving great strength.

Have greater thickness of hubs on ends.

Easier to center on pipe before pouring lead.

Cost less to install.

Book No. 11 gives full information.

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THE CHAPMAN VALVE MANUFACTURING COMPANY

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EDDY VALVE CO.

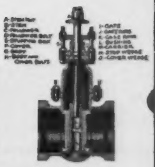
WATERFORD, NEW YORK U.S.A.

PATENT RUBBER FACED

EDDY FIRE HYDRANT

Section of Taper Seat-Valve.

Hydrant with Independent Nozzle Cut-off.



Section of Parallel Seat-Valve.

Section of Vertical Check-Valve.

Section of Vertical Foot-Valve.

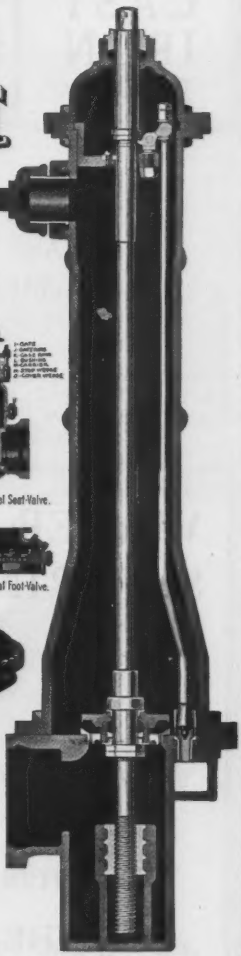
Horizontal Check-Valve.

Vertical Foot-Valve.

Hydrant with Water Crane Attachment.

Indicator Post.

Water Crane with Automatic Drip Valve.



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...OF...

CAST IRON PIPE

...AND ..

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
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WATER WORKS SUPERINTENDENTS!

Is your per capita consumption too high?

Do you account for less than 85% of your pumpage?

Are you receiving full revenue from your manufacturing consumers?

If any of these problems confront you, write us at once, without obligation, and let us tell you about our PITOMETER SURVEYS.

THE PITOMETER COMPANY

Engineers

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Philadelphia is most bountifully provided with fresh water, which is showered and jerked about, and turned on, and poured off, everywhere. The water-works, which are on a height near the city, are no less ornamental than useful, being tastefully laid out as a public garden, and kept in the best and neatest order. The river is dammed at this point, and forced by its own power into certain high tanks or reservoirs, whence the whole city, to the top stories of the houses, is supplied at a very trifling expense.

— *"American Notes" by Charles Dickens.*

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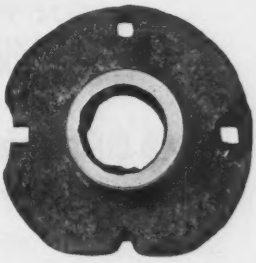
In 1842 Charles Dickens wrote the above description of the Philadelphia Water Works. At that time cast iron pipe, in Philadelphia, had been delivering water faithfully for 25 years. Nor was its usefulness nearly over. In 1915 the pipe illustrated was removed, though still in good condition after almost a century of service, to make way for a line of larger capacity.

Write to the Publicity Department, Burlington, for booklet "98 Years of Excellent Service."



Section of 1817 line

United States Cast Iron Pipe & Foundry Co.

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THE A. P. SMITH MANUFACTURING CO.

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Manufacturers of

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Economic Lead Furnaces,
Corporation and Curb Cocks, Brass and Aluminum Castings.
Also General Supplies for Water and Gas Works.

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CAST IRON
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Special Castings, Fire Hydrants, Valves
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WOOLWORTH BUILDING 233 BROADWAY
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Over 100 Water Departments
use
LEAD-LINED IRON and TIN-LINED PIPES
for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

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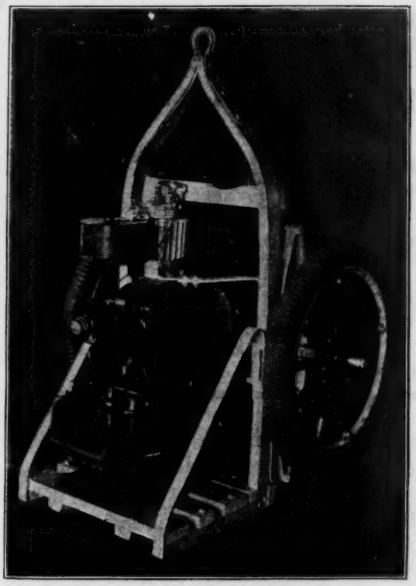

EDSON

TRAILER PUMP UNIT

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Light
Compact
Efficient

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Warren Foundry and Pipe Co.

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LARGE STOCK ENABLES US TO MAKE QUICK SHIPMENTS

Twelve Reasons Why

YOU SHOULD USE

Trade "LEADITE" Mark

Registered U. S. Patent Office

FOR

Jointing Water Mains

1. **DURABILITY.** Leadite joints increase in strength with age.
2. **NO CAULKING.** Leadite joints require no caulking, because the Leadite adheres to the pipe, making a water-tight bond.
3. **COMPARATIVE QUANTITIES.** One ton of Leadite is equivalent to four tons of lead.
4. **LABOR SAVING.** Saves caulking charges and digging of large bell-holes, and reduces the cost of trench pumping to the minimum.
5. **COST.** Its use saves 50 to 65 per cent. over lead, owing to the saving effected in material and labor.
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7. **TRANSPORTATION.** Considerable freight charges are saved because Leadite is lighter than lead.
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9. **FUEL.** Saves fuel because you melt only one ton of material instead of four, and not as much heat is required either.
10. **DELIVERY.** We can make prompt shipments.
11. **DAMAGE SUITS.** Claims for damages caused by joints blowing out are prevented because Leadite joints will not blow out under any pressure.
12. **USERS.** Progressive water works all over the country use Leadite.

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P. E. KELLY, New England Representative

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The Celebrated "ULCO"

LEAD WOOL

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For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

As compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

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Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder, White Lead and Red Lead.

HIGHEST QUALITY SOFT BRANDS

PIG LEAD

TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS PER POUND

Join Your Water Mains

WITH

LEAD-HYDRO-TITE

TRADEMARK

AND CUT YOUR EXPENSES

50% FIRST COST

50% SMALLER BELL HOLES

75% HANDLING

100% CALKING

OUR PROPOSAL

That the prospective users purchase a trial lot of 1 to 5 bags, and that this be used under the direction and according to the instructions of our representative.

If, after a trial, the purchaser is not satisfied with the material, any surplus not in use to be returned to the Lead-Hydro-Tite Company, and no charge to be made for any of the Lead-Hydro-Tite furnished.

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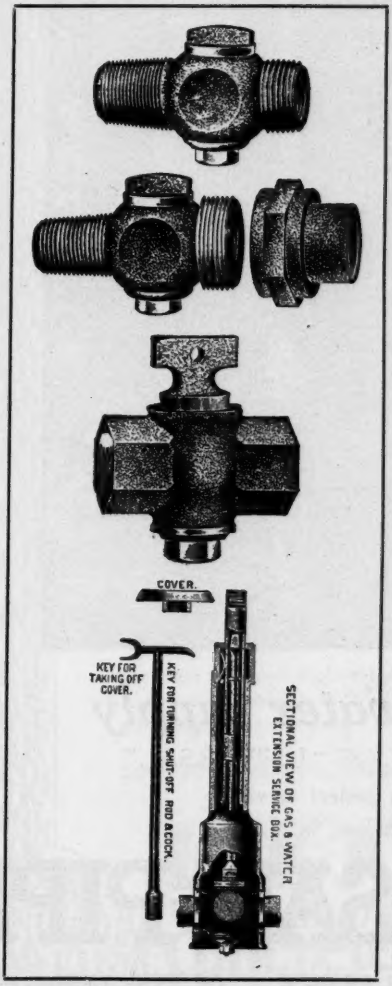
BOSTON, MASS.

PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND

TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS

"The Goods That Please"



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We have them to meet every requirement

ORIGINAL

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Extension Service Boxes of proven advantages

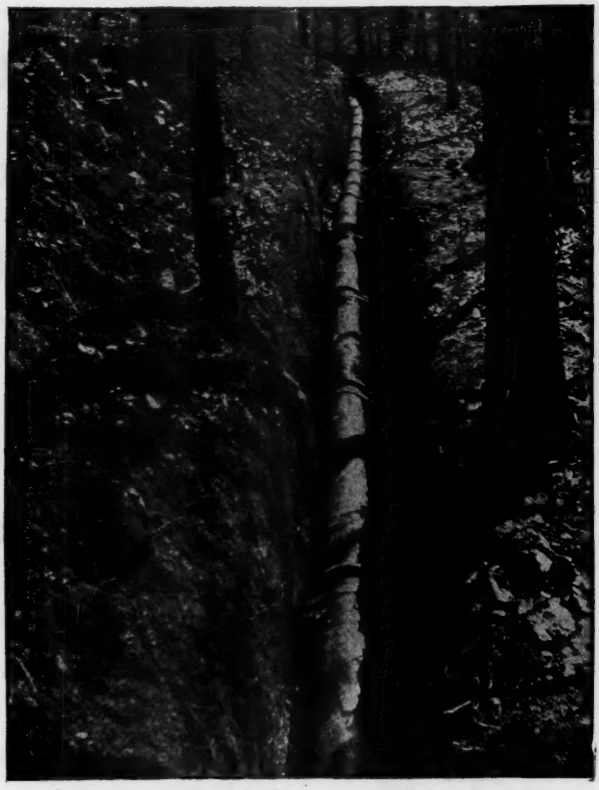
Let us send at our risk, on 30 days' trial, a

Payne's Patent Tapping Machine

which is recognized to be the most easily operated owing to the few working parts.

Hays Mfg. Co., ERIE PENNSYLVANIA

Established 1869



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giving perfect service
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no packing no calking no bell holes

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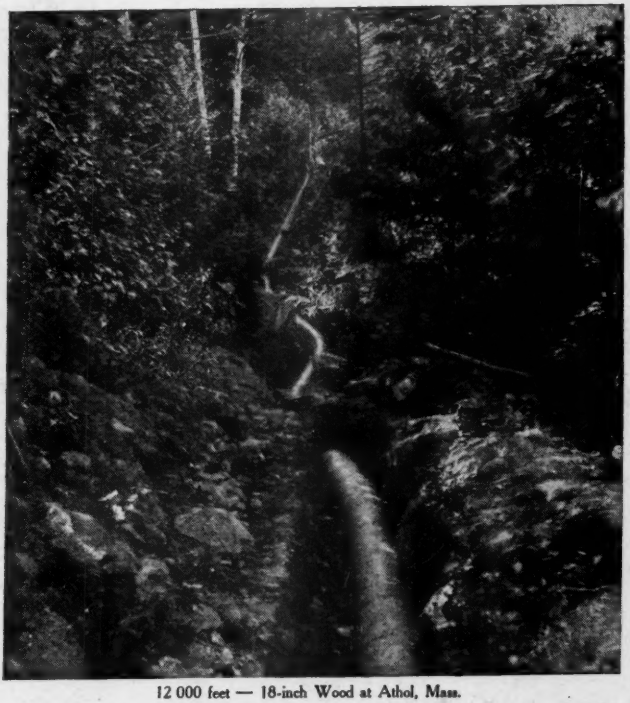

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